Water Power

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

PRICE 2/6 SEPTEMBER 1952

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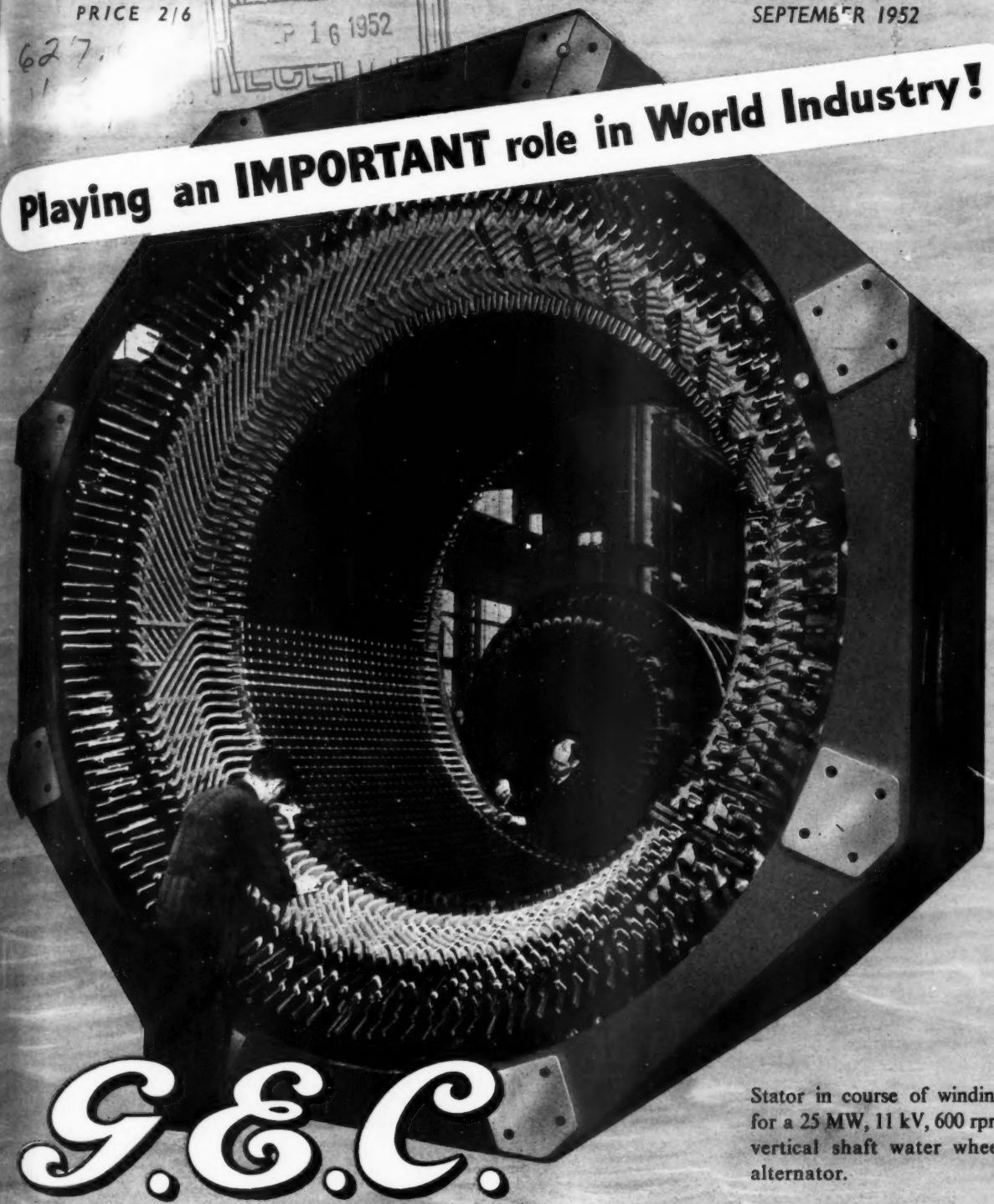
Playing an IMPORTANT role in World Industry!



G.E.C.

Stator in course of winding for a 25 MW, 11 kV, 600 rpm vertical shaft water wheel alternator.

HYDRO ELECTRIC PLANT

THE GENERAL ELECTRIC CO. LTD · MAGNET HOUSE · KINGSWAY · LONDON · W.C.2

WE SOMETIMES TEND TO OVERLOOK the achievements of the electrical engineering pioneers of the past because to our eyes their designs look clumsy, old-fashioned and ill-conceived. Yet, when we take the trouble to look closer into the subject, we find that many of the first principles they laid down 50 years ago still apply today.

An early electrical engineer who aptly illustrates our point was Henry William Clothier. As far back as 1906, he had produced fundamentally new designs for what he described as Ironclad Switchgear. All over the world much of the switchgear in use and being manufactured and installed is based on the principle laid down by Clothier. Thus, the industry continues to benefit from his work. He was a switchgear specialist. He taught other men to be specialists and helped build the specialist company of Reyrolle.

Our primary concern is designing and producing switchgear, so if you have any transmission or control problems, why not talk to us.

If you want to talk switchgear ... talk to Reyrolle

A. REYROLLE & COMPANY LIMITED · HEBBURN · CO. DURHAM

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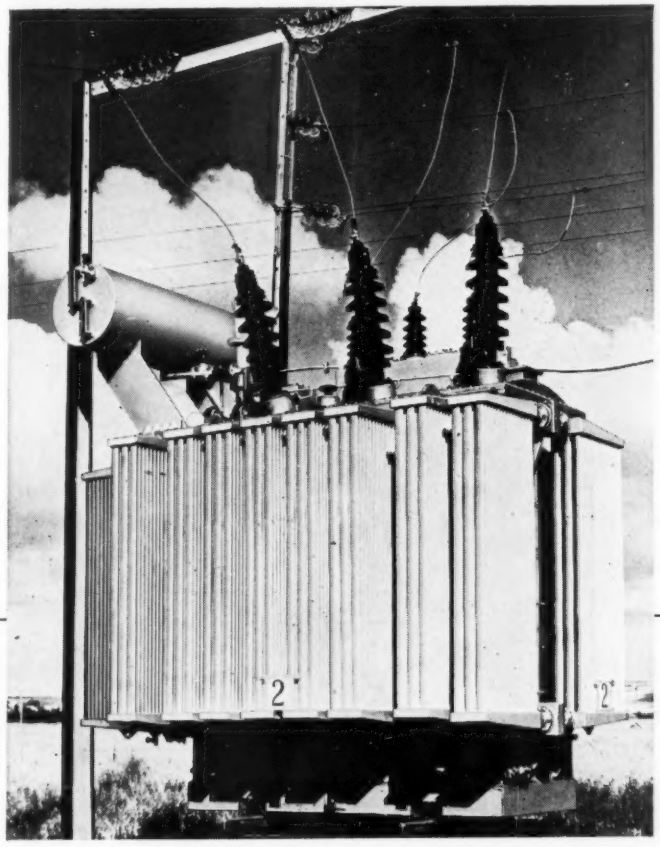

Twenty-eight transformers for South Australia

Twenty-eight 12·5 MVA transformers are being supplied by 'ENGLISH ELECTRIC' to the Electricity Trust of South Australia as part of their development programme. These transformers are three-phase units with the main windings auto-connected for a voltage ratio of 66/33 kV. A delta connected tertiary winding provides a supply at 7·6 kV; coupled to it is an inter-star balancer in the same tank.

The ENGLISH ELECTRIC Company has specialised for many years in the design and manufacture of transformers of all types up to the largest sizes and the highest voltages.

'ENGLISH ELECTRIC'

transformers

THE ENGLISH ELECTRIC COMPANY LIMITED, QUEENS HOUSE, KINGSWAY, LONDON, W.C.2

Transformer Department, Stafford

WORKS: STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL · ACCRINGTON

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Quarry to Batching PLANT

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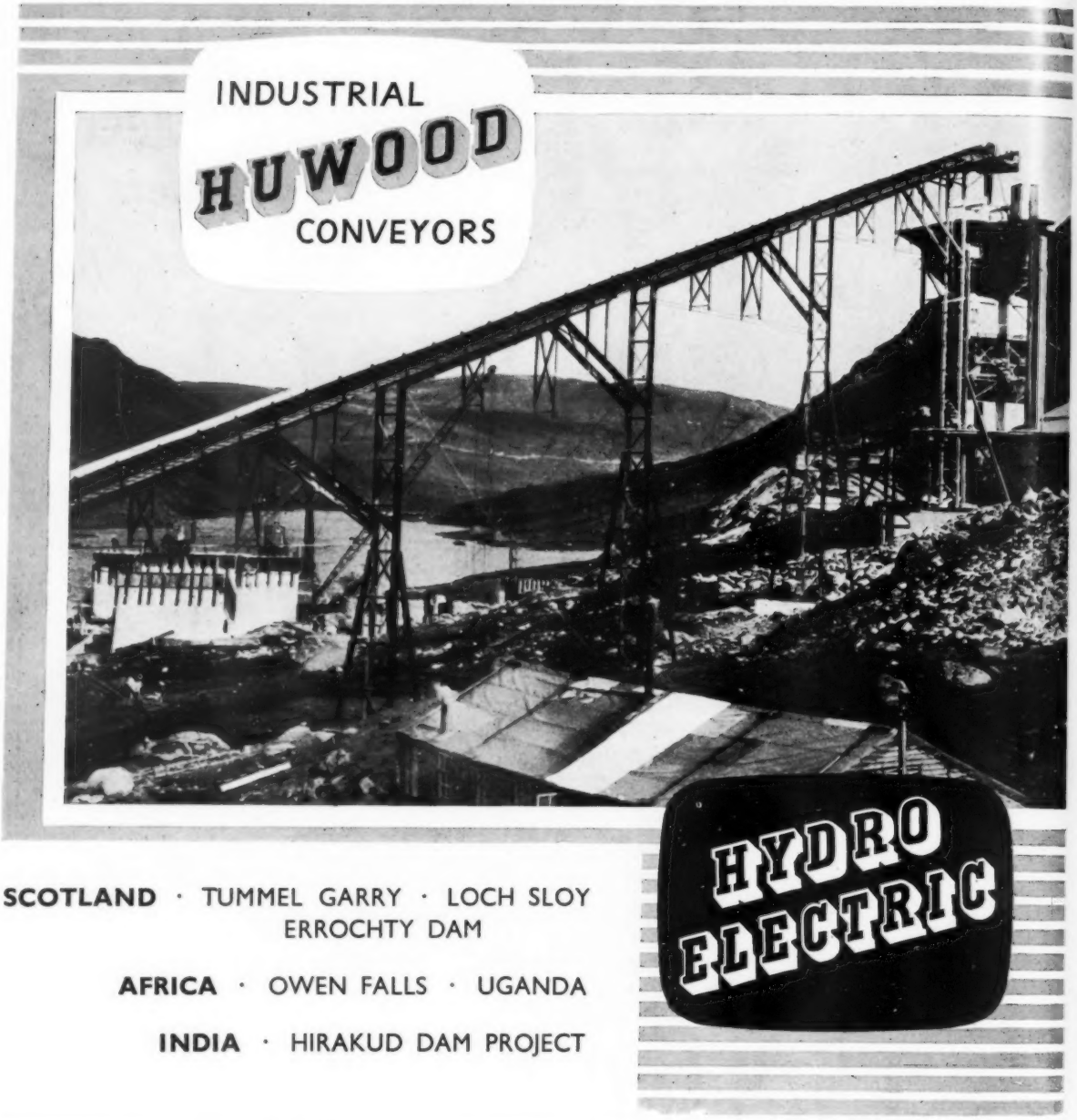

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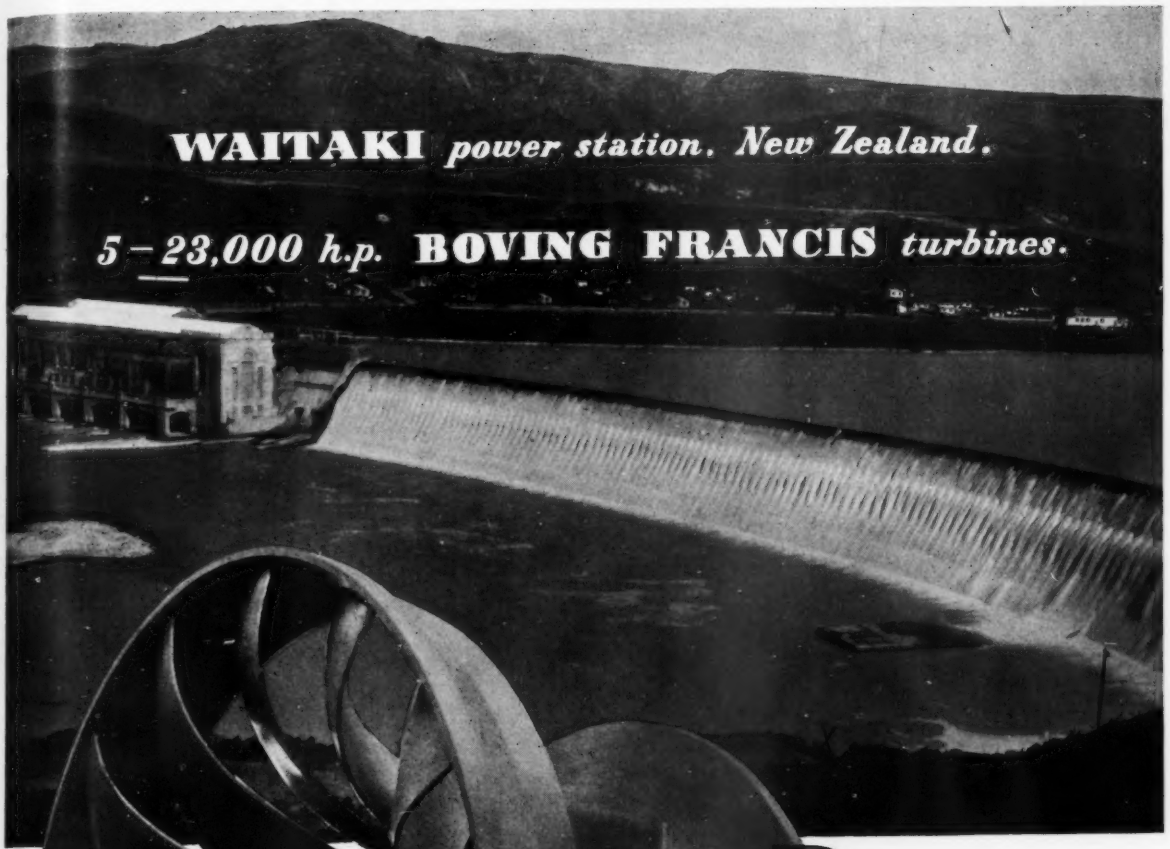

Boving

The Waitaki power station is at present being extended with two BOVING-FRANCIS turbines. The station will then contain seven main turbines, all but the third and fourth being supplied by BOVING. The fabricated runner for one of these turbines is illustrated.

RATING	
Nett head	70 ft.
Output	23,000 b.h.p.
Speed	125 r.p.m.
Type	Vertical BOVING-FRANCIS
Diameter of runner	12.3 ft.

Boving
E. COMPANY LIMITED

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B.C.11

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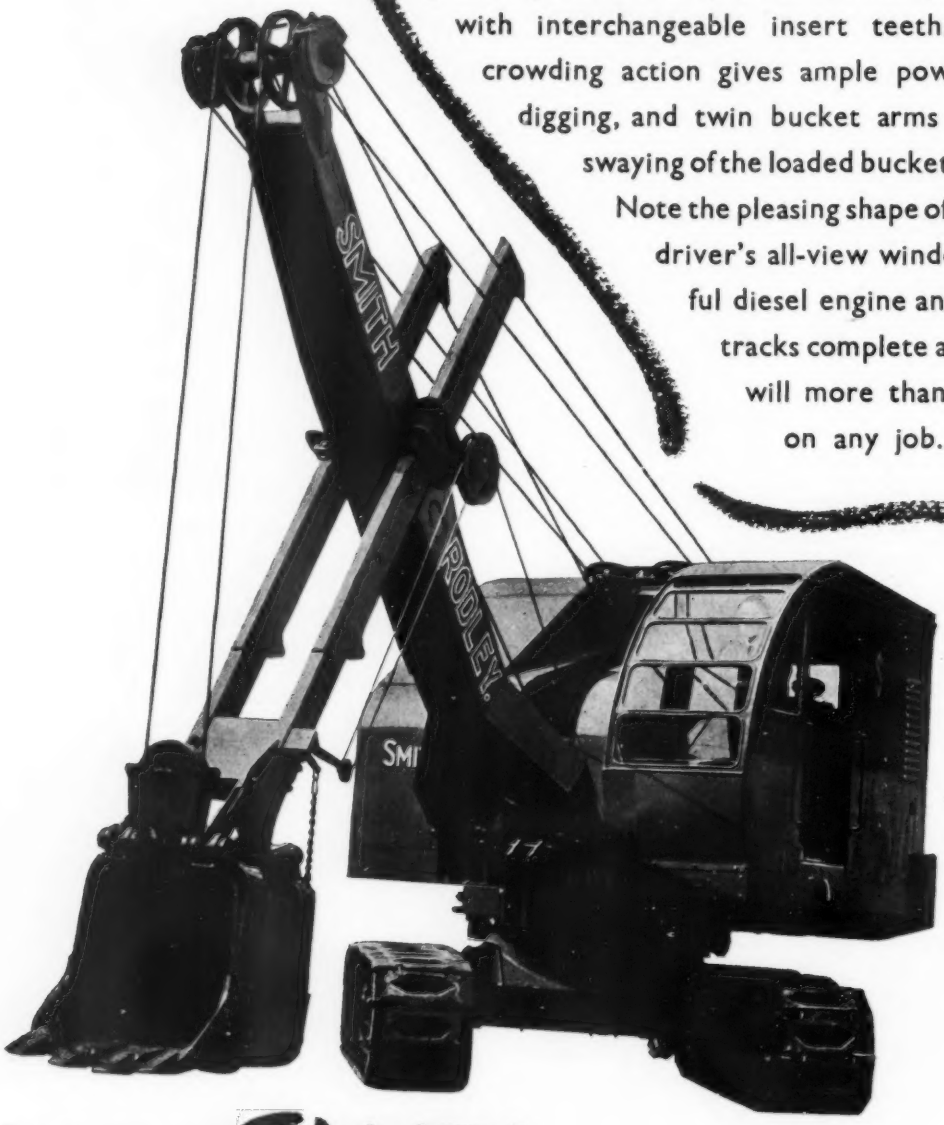
. . . at the sturdy lines of the Smith '21' Universal Excavator. The robust face shovel, with a capacity of ¾ cubic yard, has a lip plate cast in special alloy steel with interchangeable insert teeth. Automatic crowding action gives ample power for heavy digging, and twin bucket arms eliminate any swaying of the loaded bucket when slewing. Note the pleasing shape of the cab and the driver's all-view windows. A powerful diesel engine and wide crawler tracks complete a machine which will more than earn its keep on any job.



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CRANE & EXCAVATOR WORKS, RODLEY, LEEDS

ESCHER WYSS ZURICH

Escher Wyss has developed to a very high degree the design and manufacture of high-head Francis turbines. The above runner is that of a turbine developing 65,000 h.p. under a head of 1,050 ft. Similar turbines, but for larger outputs and heads, are in course of construction.

We further specialize in Kaplan and impulse turbines up to the largest outputs and heads, as also in large storage pumps and other hydraulic equipment.

Our experience in manufacture and in installation work all over the world is at your disposal.

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for Outdoor Erection and Voltages up to 380 kV

① High reliability
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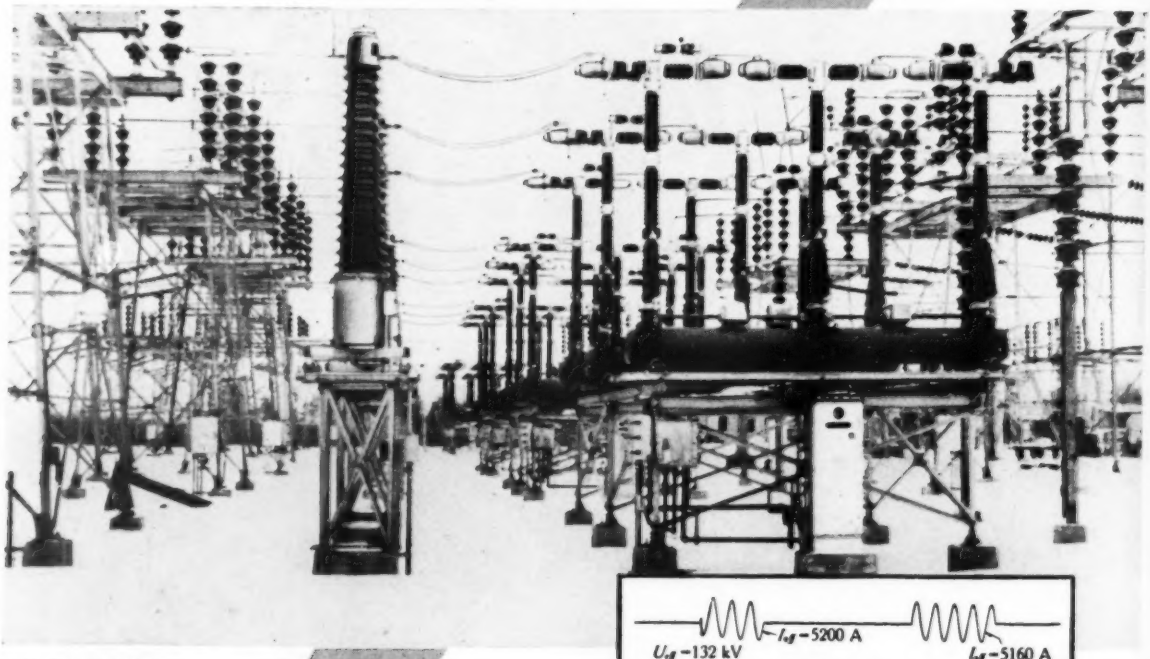
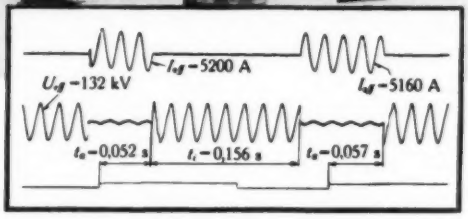


Brown Boveri 220-kV air-blast circuit-breakers n a Canadian outdoor station



t_a = Breaking times
t_t = Dead time

For reliable system operation install our air-blast high-speed circuit-breakers with automatic high-speed reclosing, in conjunction with our rapid and selective relays for electrical-system protection. Over 10 000 indoor and 1200 outdoor high-voltage air-blast circuit-breakers have already proved their worth in service over a period of many years.

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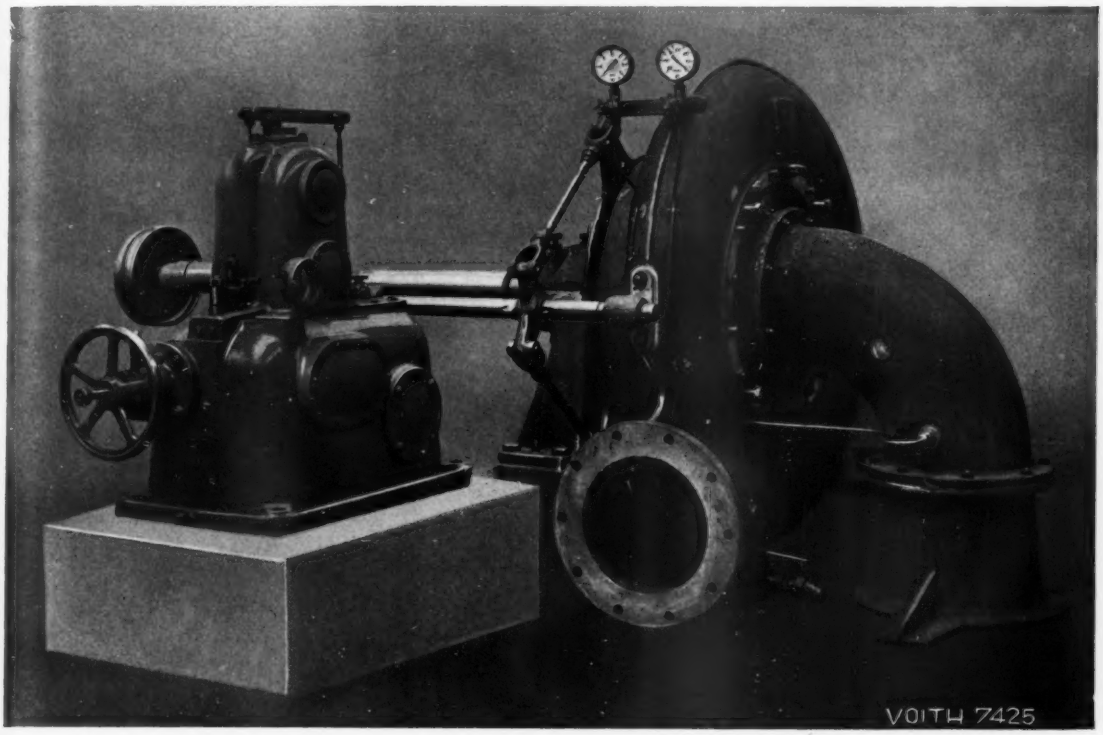
Voith Water Turbines

for small power stations



Small Francis Spiral Turbine, 215 H.P. at 36.8 m head for a power station on the Rio Hidalgo (Mexico)

Kaplan, Francis and Impulse Turbines

gear drives, speed governors, shut-off valves
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Since **1946** we have supplied more than **500 small-size turbines** for use in Germany and abroad

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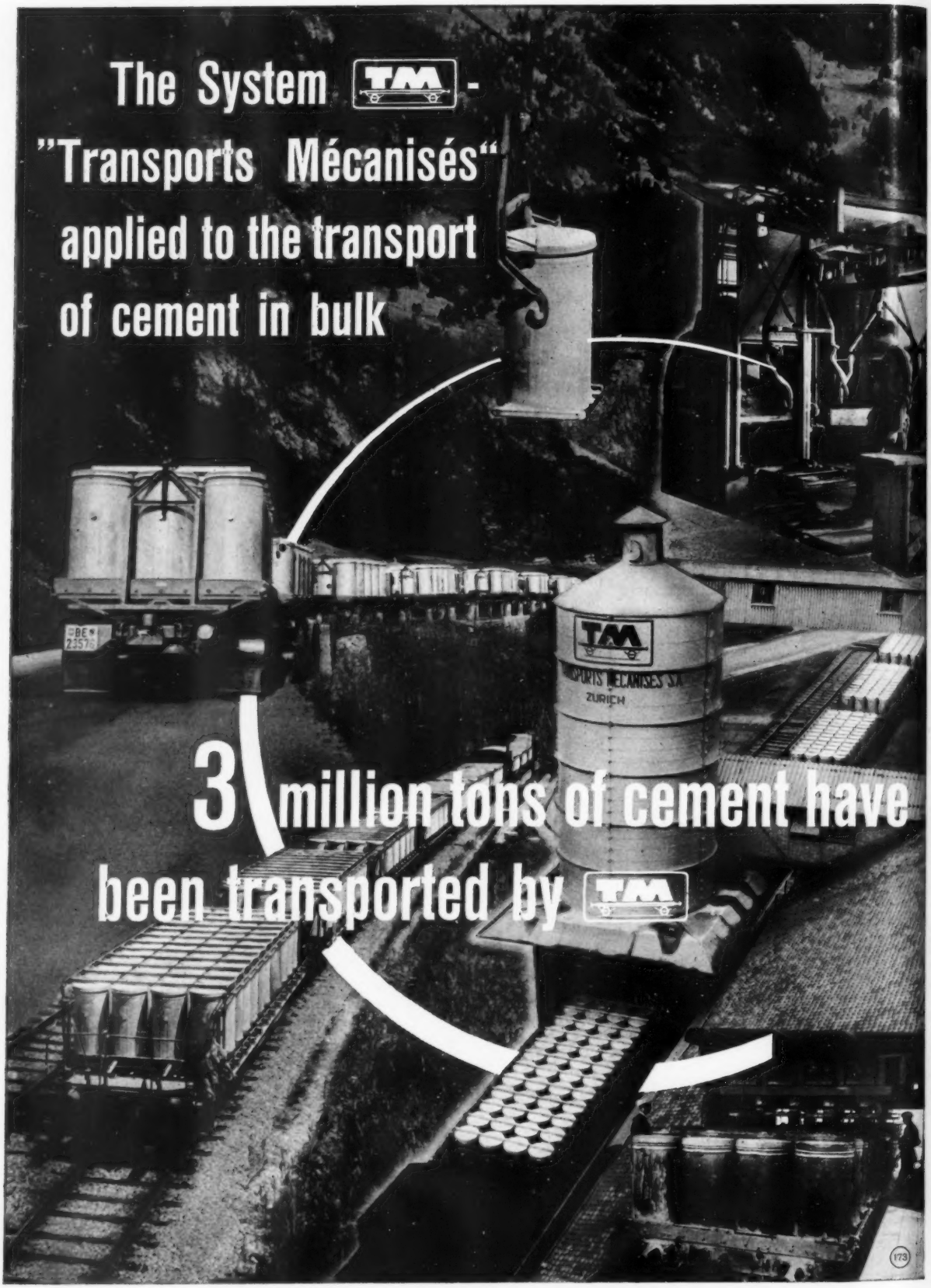
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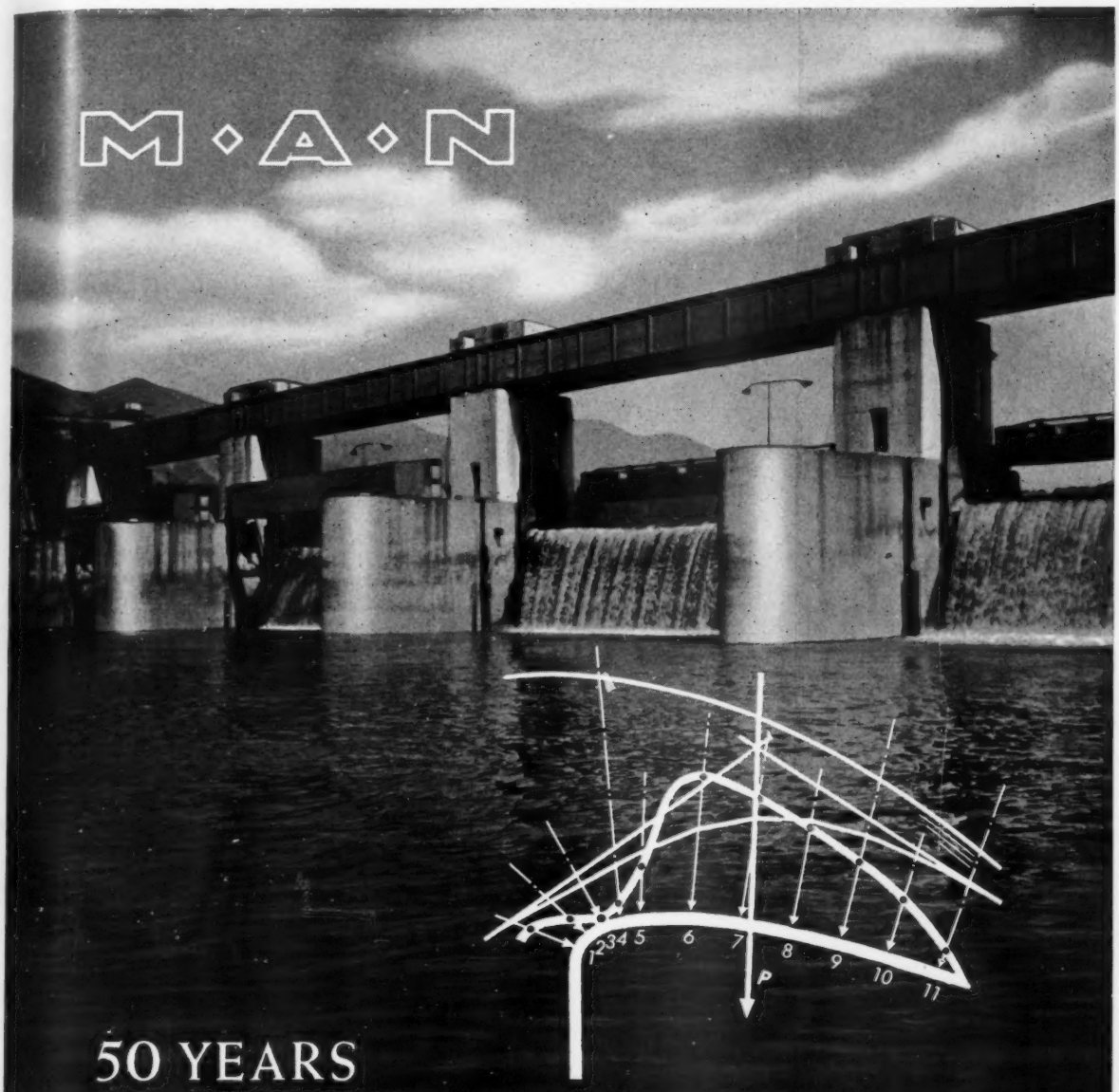

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Leffel

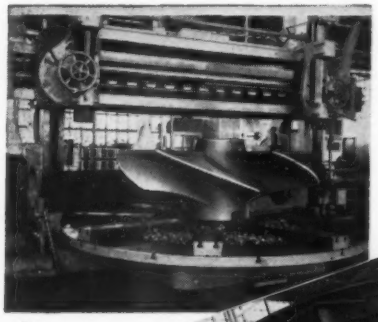
HYDRAULIC TURBINE

increases

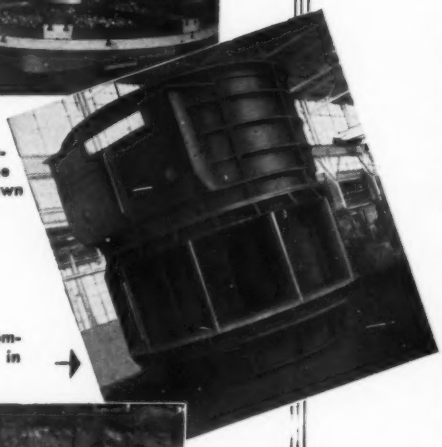
power output at

WILBUR DAM

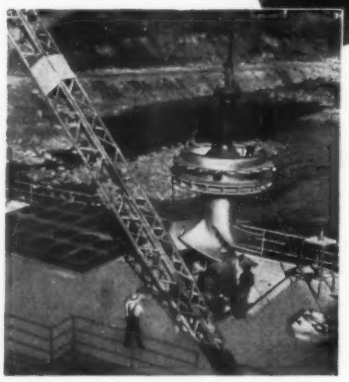
of the Tennessee Valley Authority



Cast steel propeller-type runner for the Wilbur turbine, shown on boring mill.



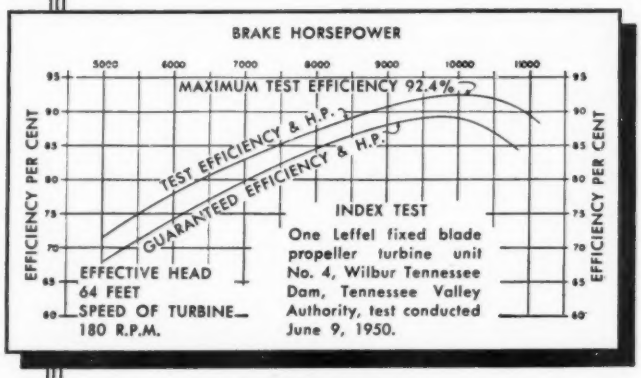
Wilbur turbine, completely assembled in the Leffel plant.



Lifting the combined runner, shaft and cover-plate during the field installation.

The Wilbur power project of the TVA is another instance where a Leffel hydraulic turbine was used for the expansion of existing power facilities. For the Wilbur installation a Leffel vertical propeller-type hydraulic turbine was used — maximum rated at 11,500 HP, under 67 feet net head, speed 180 RPM.

The Wilbur project demonstrates once again that the long-range economy and dependability of Leffel turbines make a valuable asset for any expansion or rehabilitation. Our facilities are backed by 90 years of reliable service to the water power industry. Why not let us help you with your project, whether it be expansion, rehabilitation or a new installation?



Field Test Results

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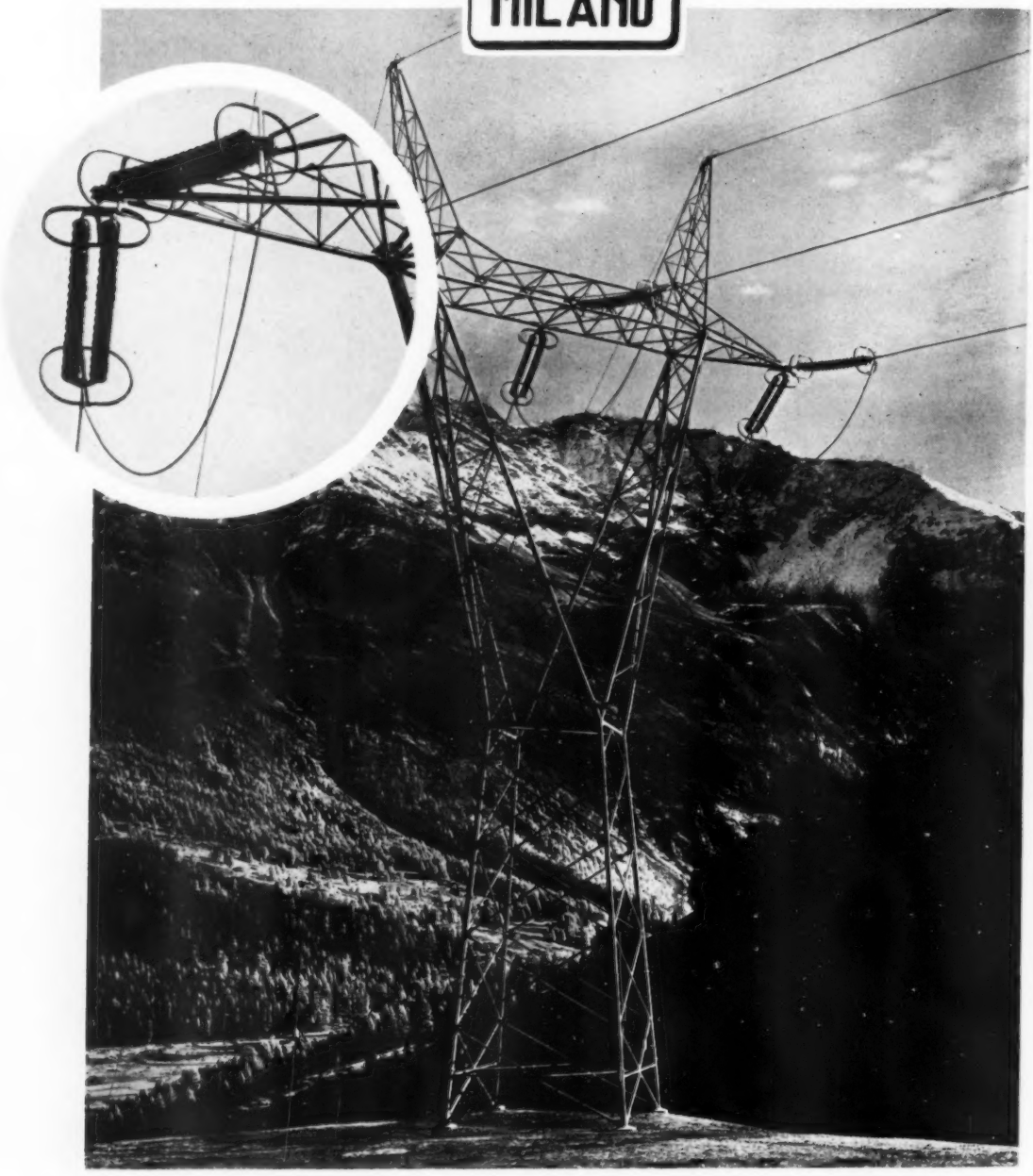

For 30 years Messrs. A. Salvi and Company, Milano, Italy, have specialised in the design and manufacture of complete equipment for Overhead Transmission Lines, including Compression Dead Ends, Assemblies and Joints. Suspension and Strain Clamps. Arching Horns. Guard Rings. Shackles. Armour Rods. Galvanized Bolts and Nuts, etc.

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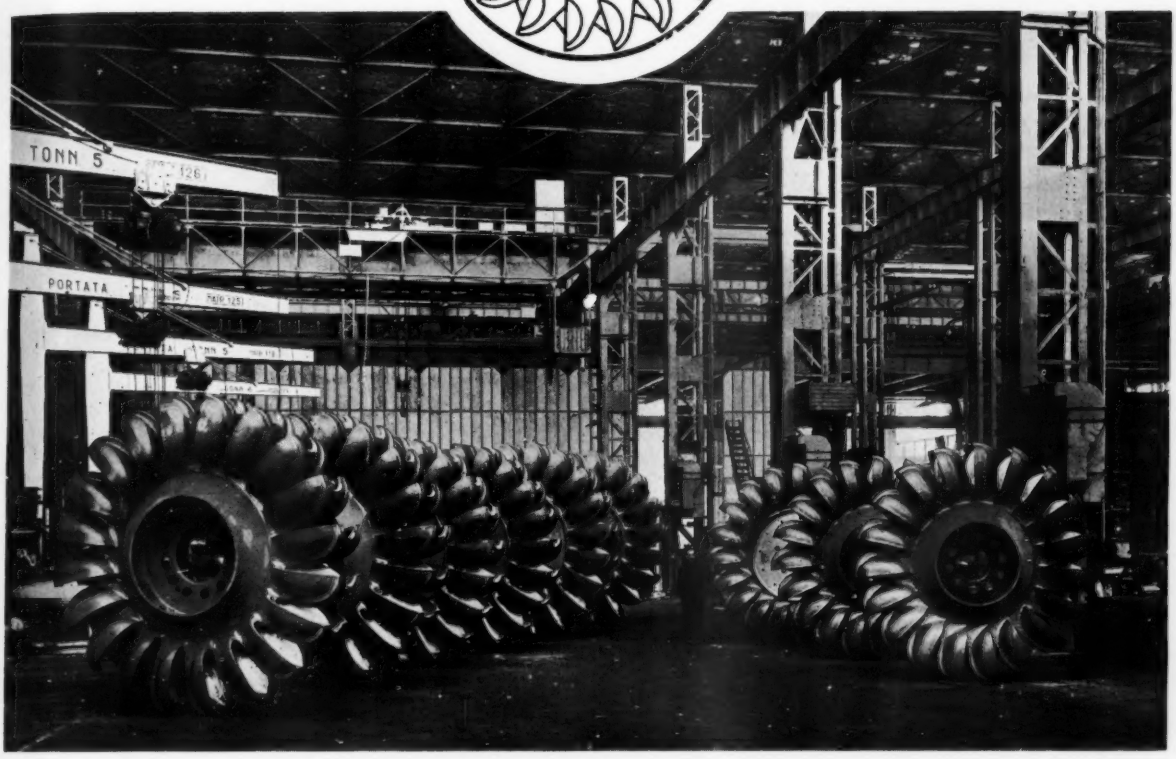
PELTON RIVA TURBINES



Cast Steel Runners for Riva Pelton Turbines of 80,000 H.P., 62,000 H.P. and 33,000 H.P.

Installations of special interest include:

PELTON TURBINES. Impulse Units for heads up to 3,940 feet and outputs up to 110,000 H.P.

FRANCIS TURBINES. Two units each of 80,000 H.P. operating under a head of 930 feet and 3 Units each of 46,200 H.P.

KAPLAN TURBINES. Two Units of 33,000 H.P. each at 167 R.P.M. under a head of 91 feet

THE TOTAL OUTPUT OF PELTON, FRANCIS AND KAPLAN TURBINES DESIGNED AND BUILT BY RIVA EXCEEDS 8,000,000 H.P.

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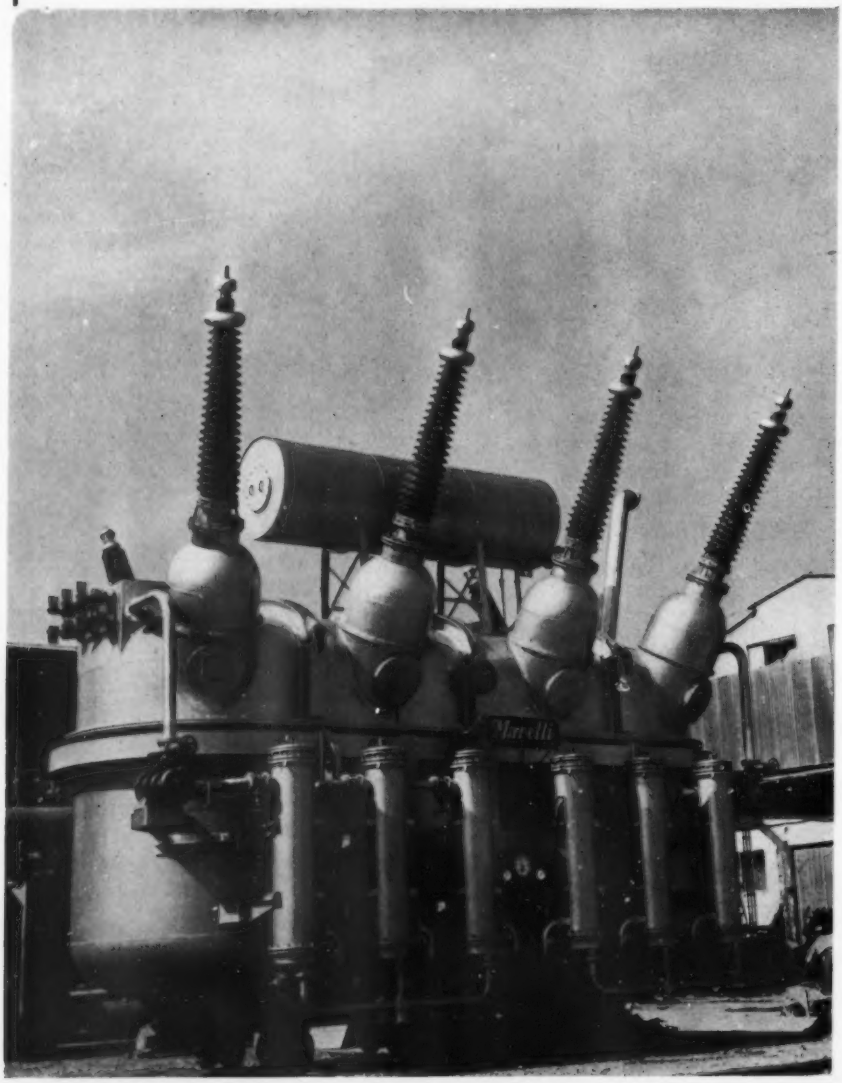

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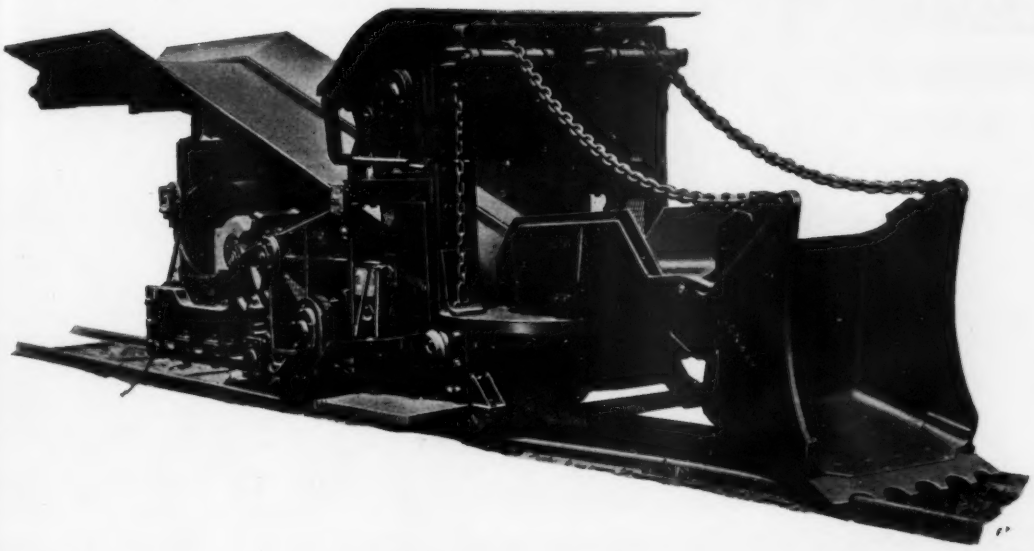
British Conway Loaders



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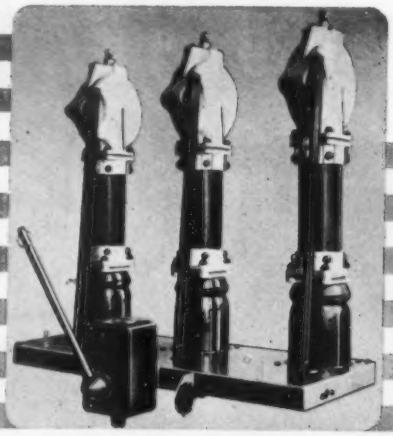

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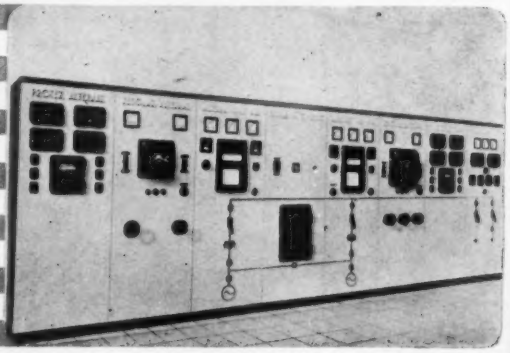
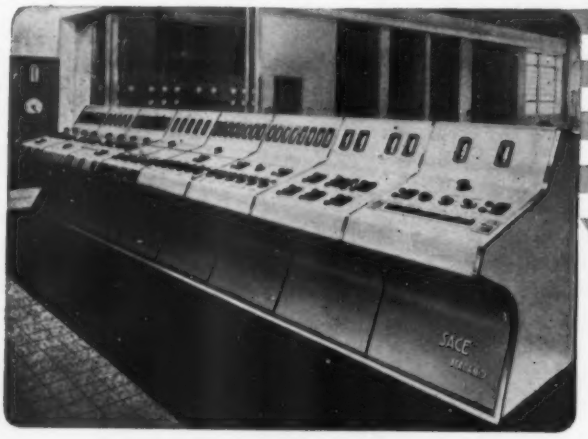
Substations
Power Stations





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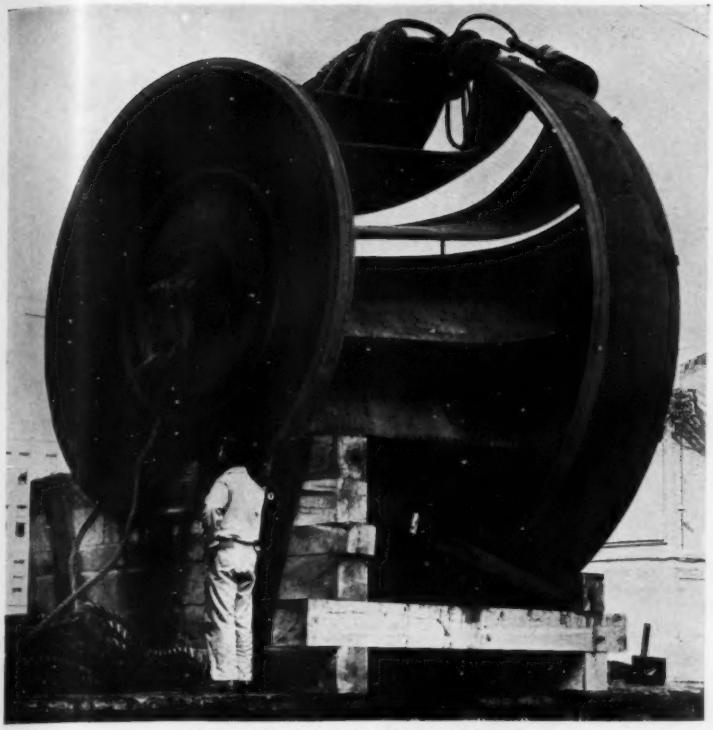

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OVER EIGHT MILLION HORSEPOWER

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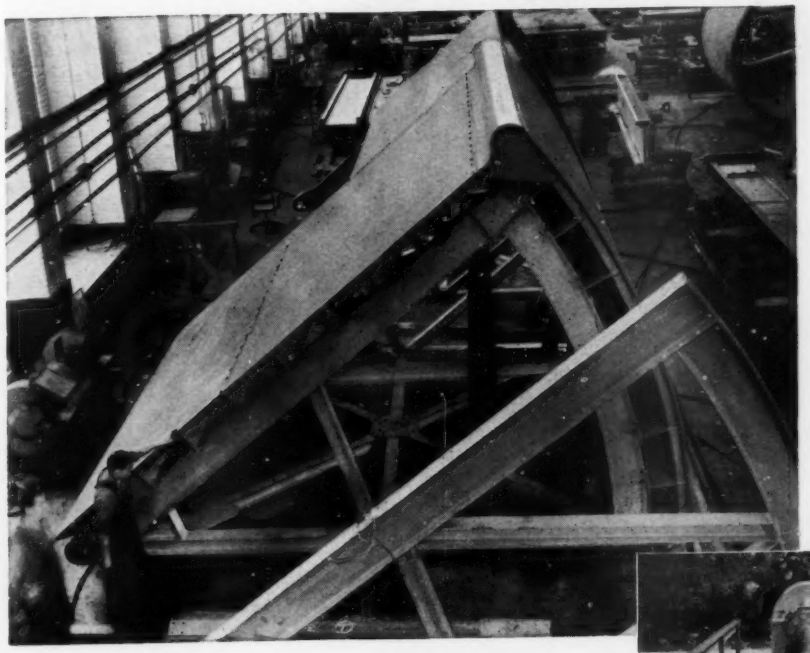
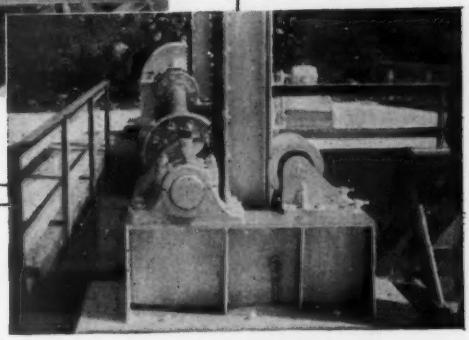
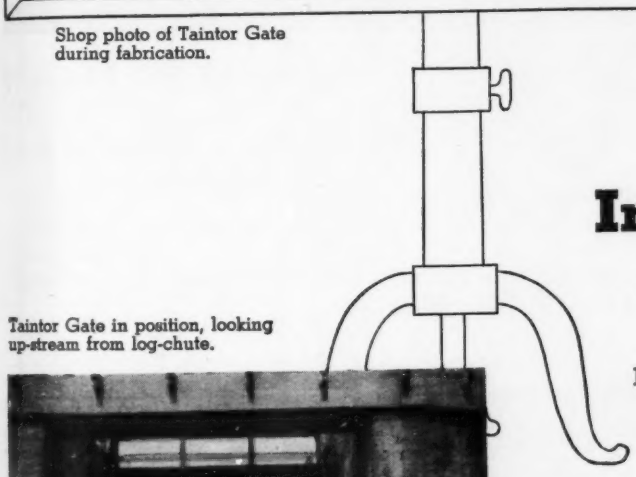


Shop photo of Taintor Gate during fabrication.



Partial view of operating mechanism.



Taintor Gate in position, looking up-stream from log-chute.

Imagineering...

In constructing most Canadian Power Dams, provision must be made for the free movement of logs. The idea of using Taintor Gates to admit water to the log chute was conceived by the Hydro Electric Power Commission of Ontario . . . the Gate and all operating mechanism was designed and fabricated by Canadian Vickers. Thus imagination plus engineering know-how achieved a new and totally satisfactory answer to an old problem.

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PORTABLE CRUSHING AND SCREENING PLANTS FOR £A 200,000,000 PROJECT

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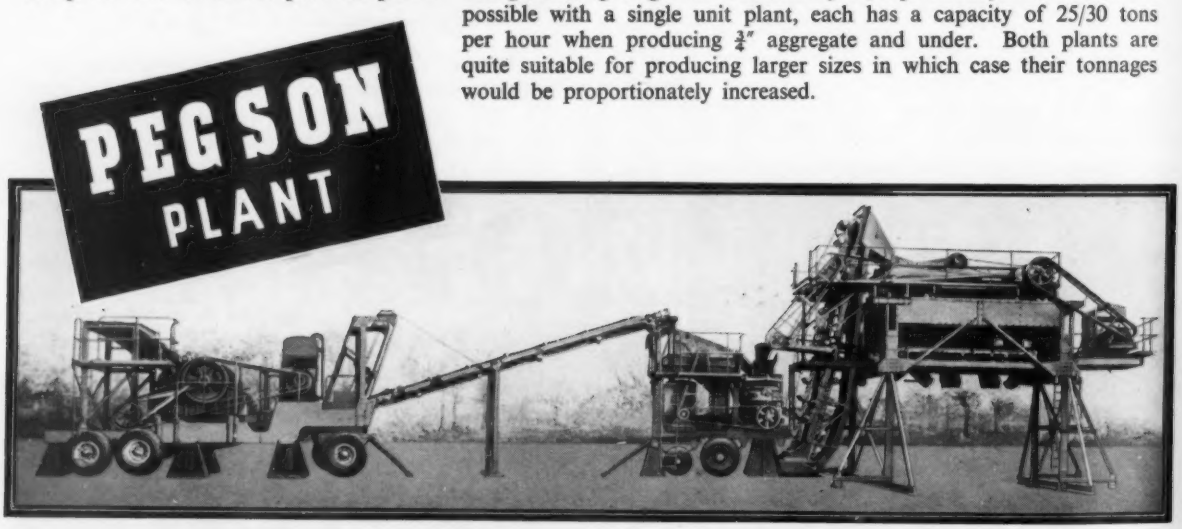

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Illustration. Hillside view of HENLEY 132kV single circuit towers overlooking Loch Luichart. (Note: The footings of one tower are above the peak of the other which is only 150 ft. distant.)

Consultants: Messrs. Kennedy and Donkin

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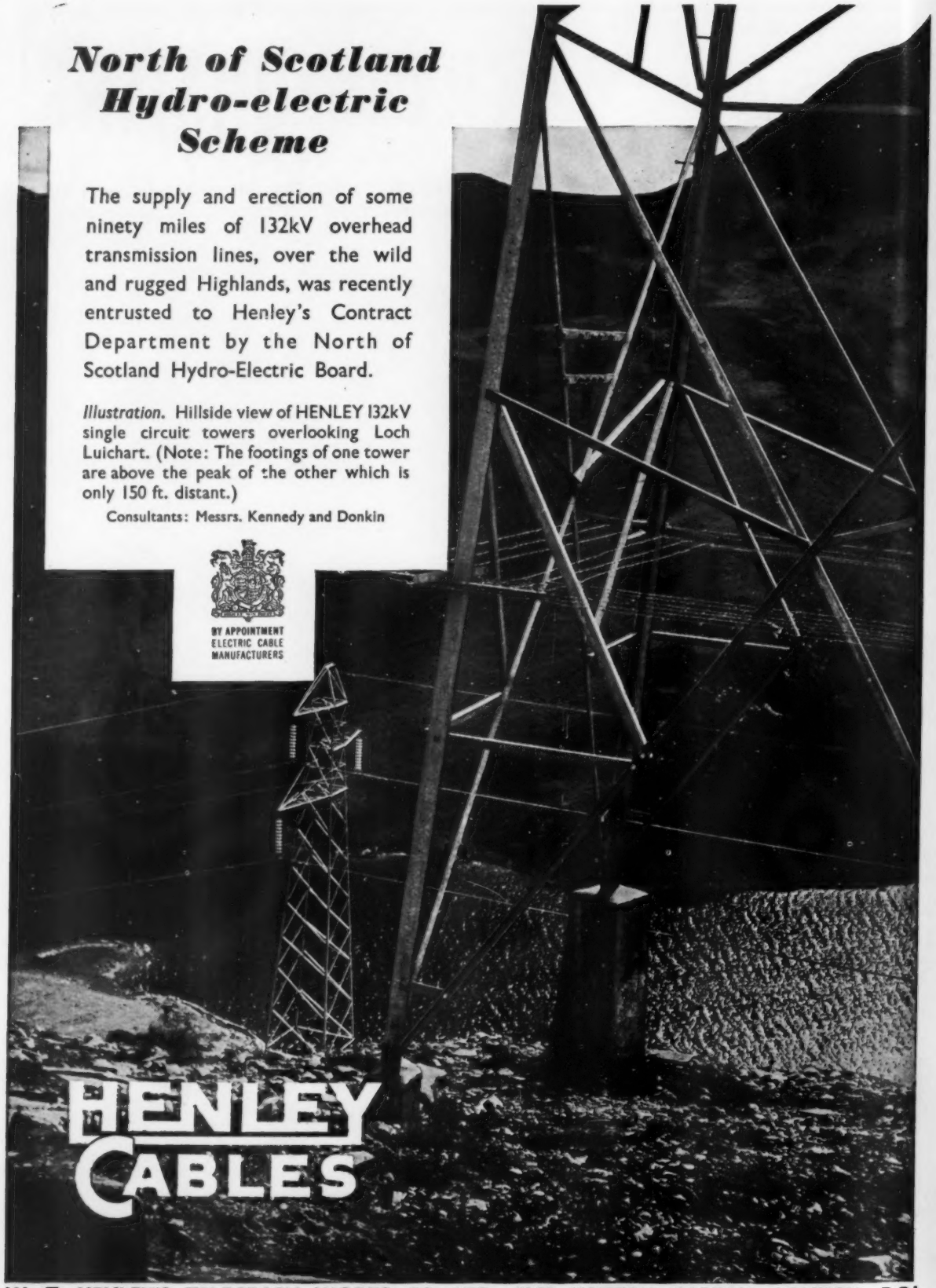

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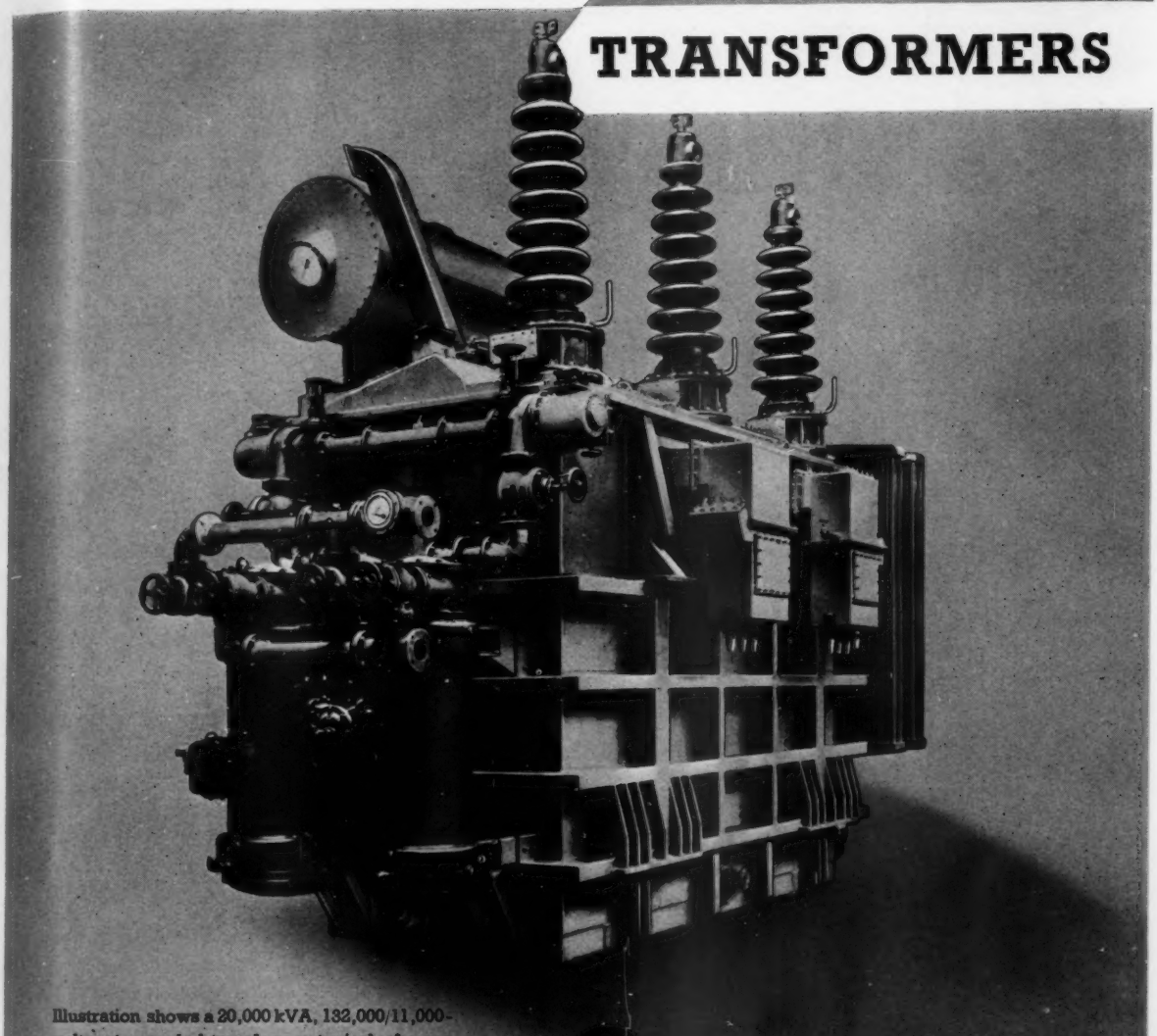

Illustration shows a 20,000 kVA, 132,000/11,000-volt water-cooled transformer typical of many supplied for Scottish hydro-electric schemes.

PEEBLES TRANSFORMERS running into millions of kVA in units up to 75,000 kVA have been supplied for use all over the world, and larger equipments for the British Super-Grid are now on order.

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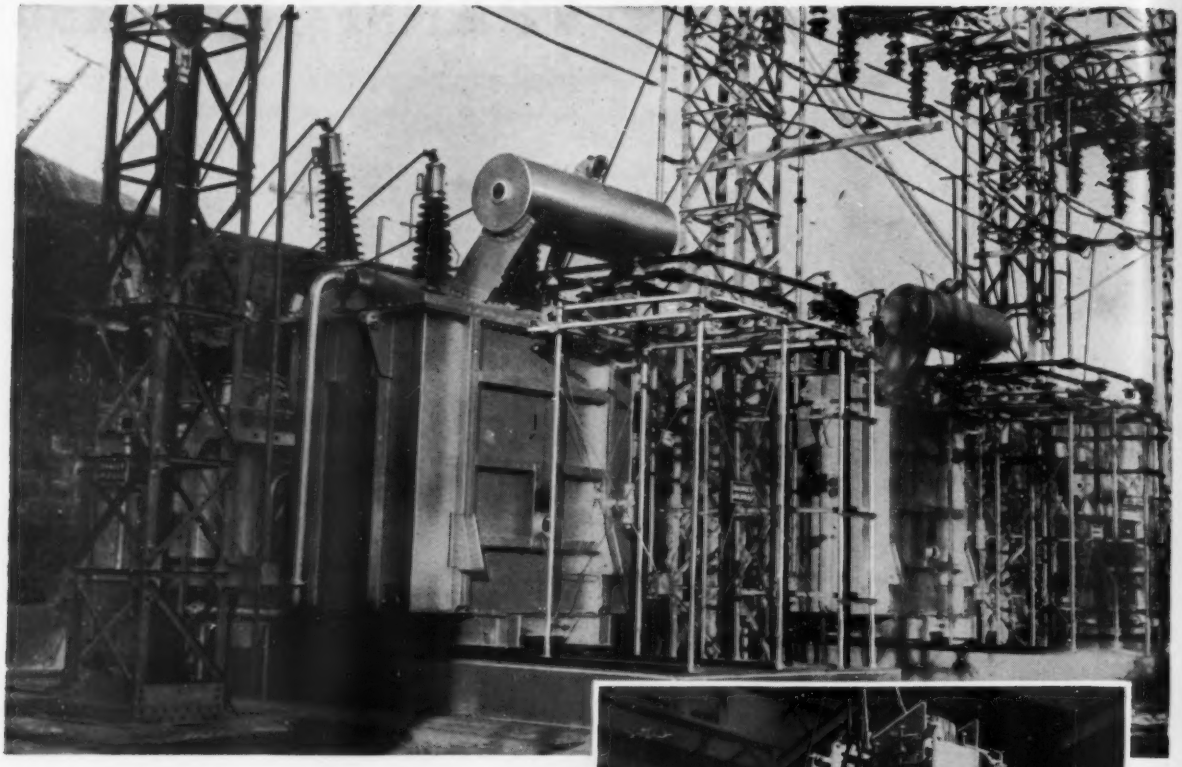

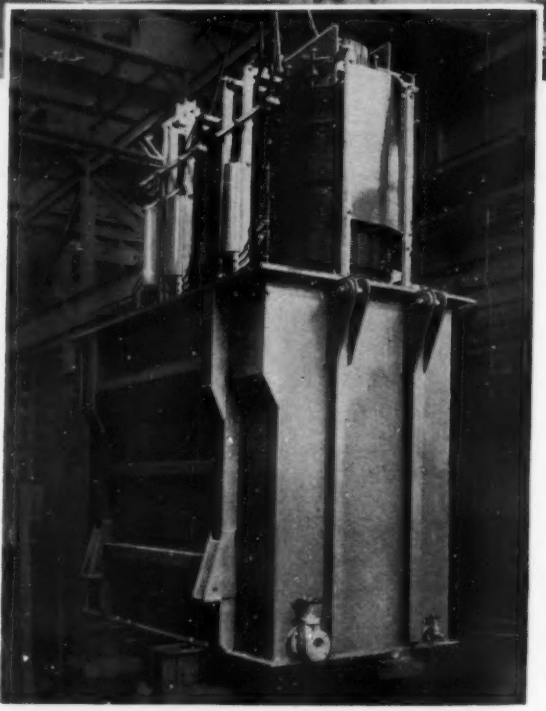

Two of the three 17,500 kVA. 11,000/66,000/110,000 volt step-up transformers, installed at the Mettur Hydro-electric Power Station for the Madras Government.

Core and coils being lowered into tank after final drying-out prior to shipment.

For all plant required for Hydro-electric Power Schemes—Consult BTH

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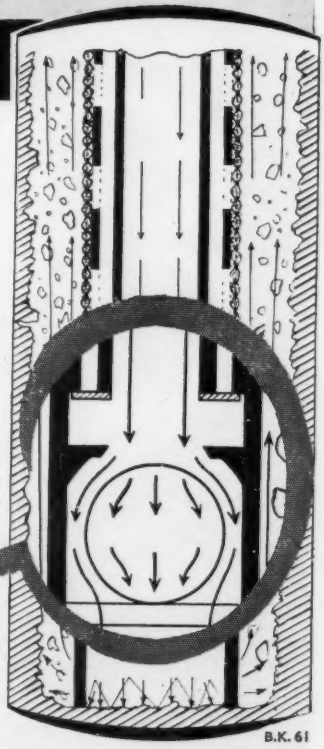

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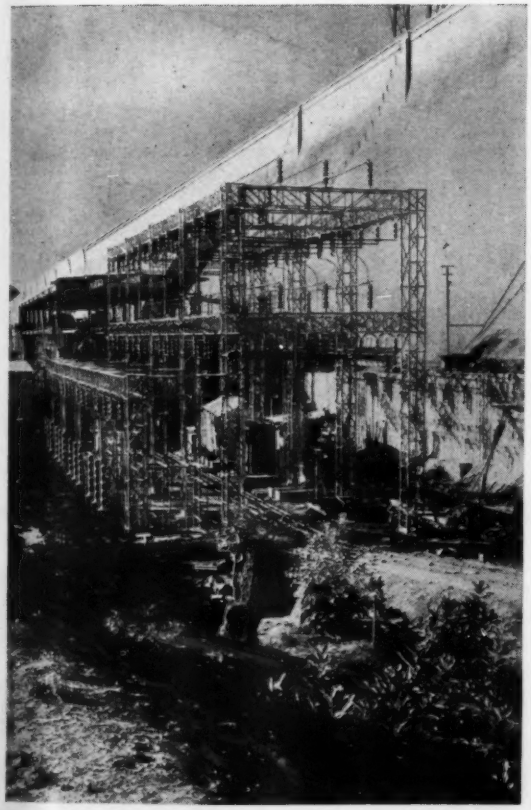

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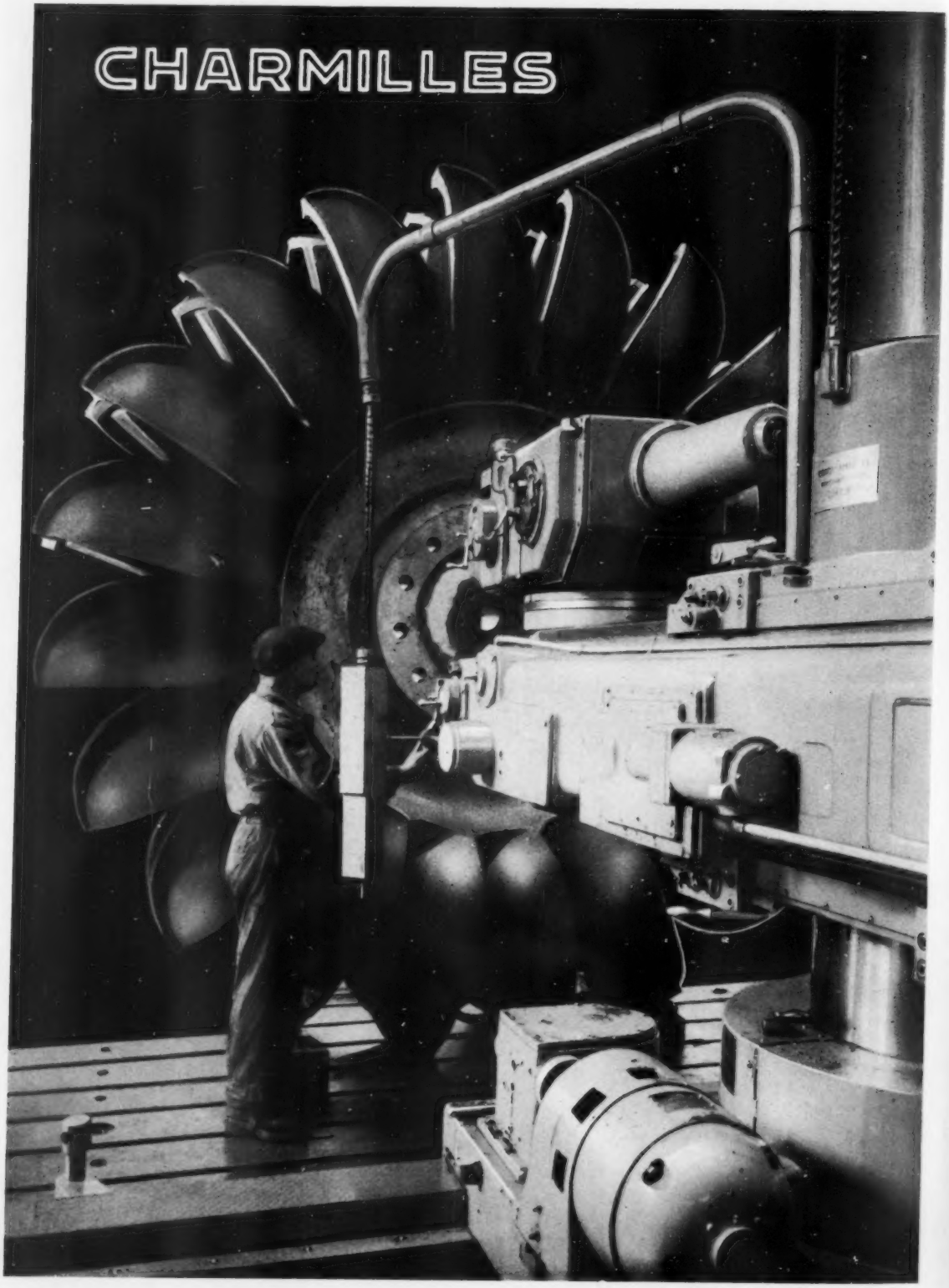

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View of Henderson Cableways during the construction of the Claerwen Dam, courtesy of the Birmingham Corporation Water Works. Contractors Messrs. Edmund Nuttall Sons & Co., Ltd

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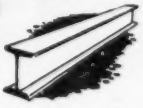
. . . with a soft "G" as in Gin ?

. . . or with a hard "G" as in  Girder ?

We say "JILKS", but with typical English perversity make it more difficult by putting "Gilbert" in front and "Gordon" behind.

Our Spanish and South American friends have no problem, they simply say "HEEL-KES"!

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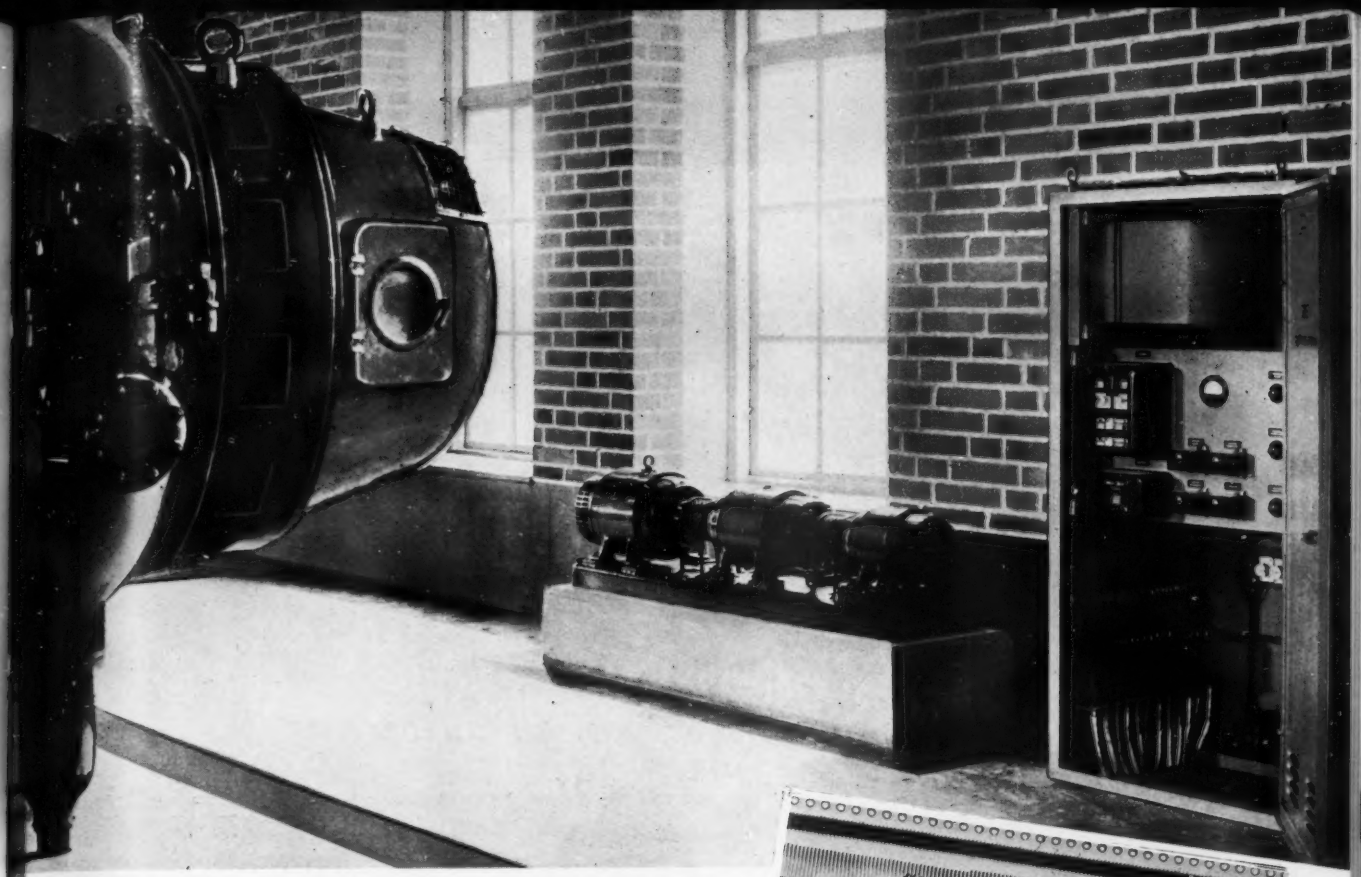
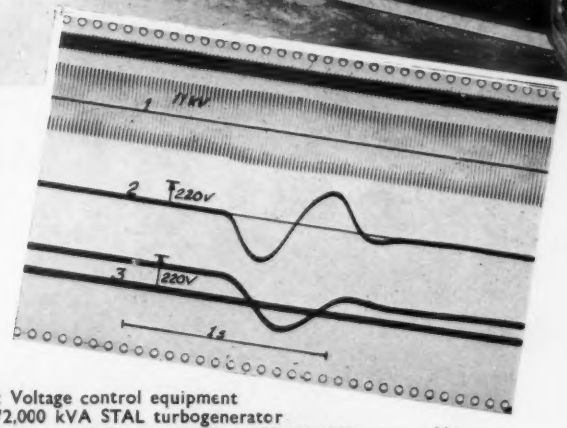
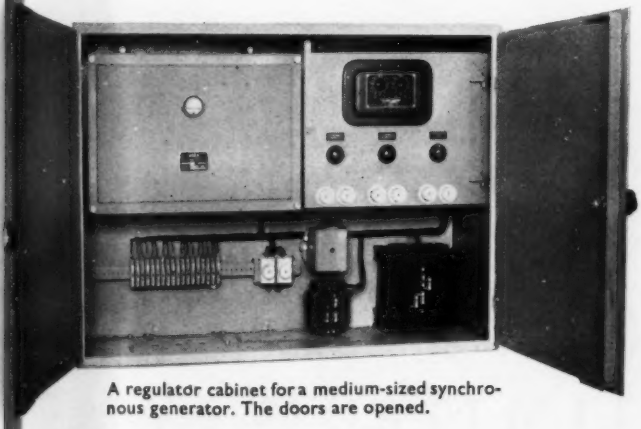


Voltage control

for synchronous machines



Above: Voltage control equipment
for a 72,000 kVA STAL turbogenerator
The oscillogram shows switching out 30,000 kVAr, $\varphi = +90°$.
1. Generator voltage. 2. Booster exciter voltage. 3. Exciter voltage.



A regulator cabinet for a medium-sized synchronous generator. The doors are opened.

The ASEA system of high speed voltage control, originally patented in 1925, has been a subject of intensive research and development, culminating in the modern transductor regulator, which embodies all the above-mentioned features. It is of unique design, providing continuous voltage control, and requiring no maintenance whatsoever. It is devoid of contacts or any other moving parts, containing only components which have a practically unlimited life. In theory it is possible to shorten the time taken for voltage regulation indefinitely, provided that the exciter equipment is appropriately designed, whereas in practice it is a question compromising between performance and economy. The ASEA high speed regulator improves the service reliability of the power plant and increases the transmission capacity of the line. In the event of short circuits or rapid load fluctuations, the excitation can rapidly be adjusted so as to increase the synchronizing torque and thus minimise the risk of hunting or dropping out of synchronism. The power line can be utilised more effectively as the regulator enables the system to be run closer to the stability limit without jeopardising the reliability of the system.

The first transductor regulator and booster exciter set were put into service in 1945. Transductor regulators manufactured since then represent an aggregate control capacity of 4,000,000 kVA or in course of manufacture, for machines up to a size of 105,000 kVA. Experience with these regulators in service has been very good. Transductor type regulators without booster exciters for small generators can be supplied within short delivery time.

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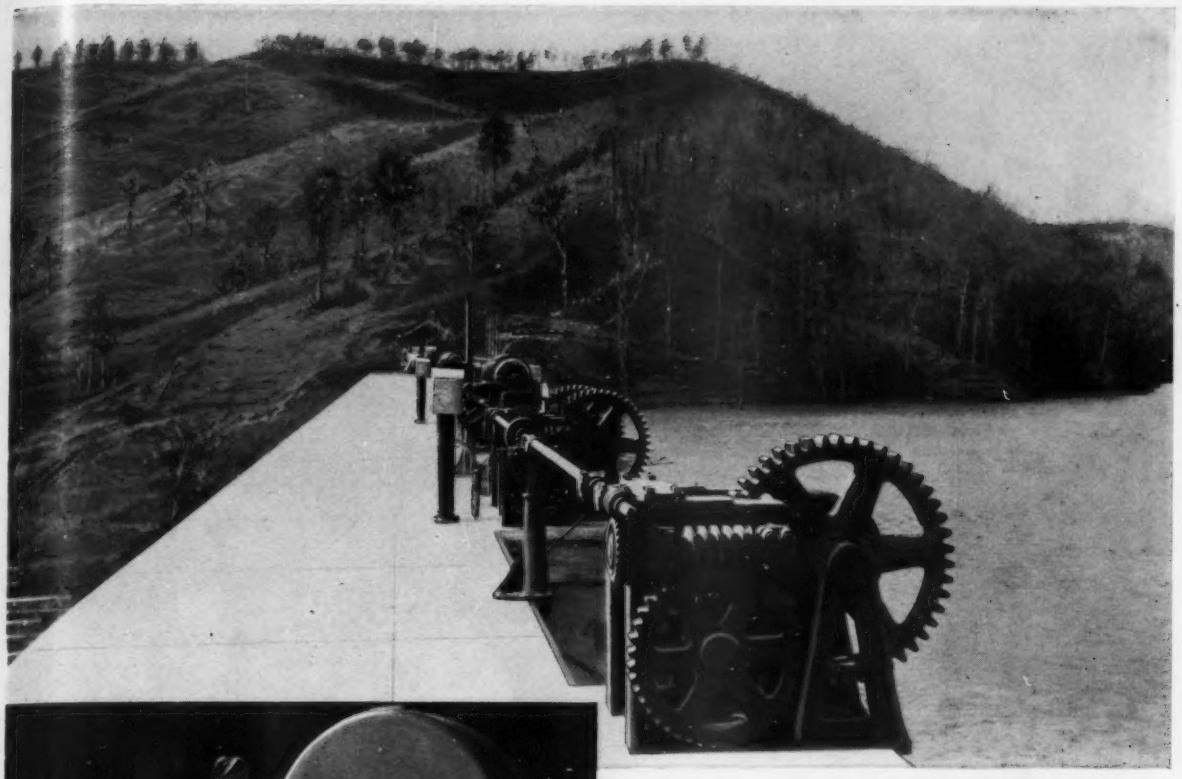

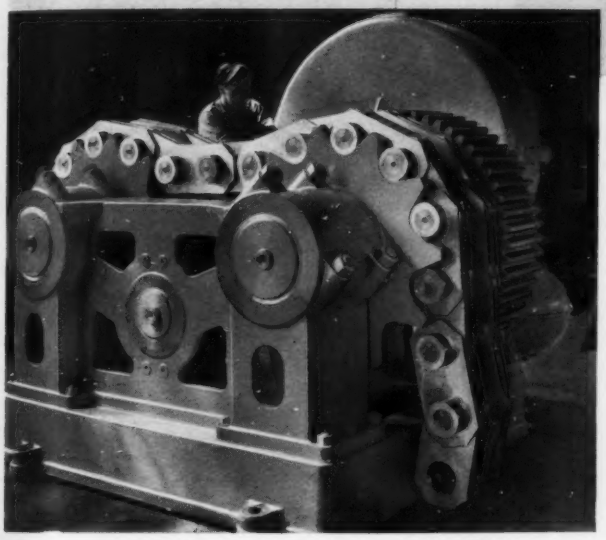

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THE PROBLEMS involved in hoisting mechanisms and gates are many and varied. The solution of them is almost a science in itself. Hence, as both are vital equipment of every water power plant great care must be given to their selection.

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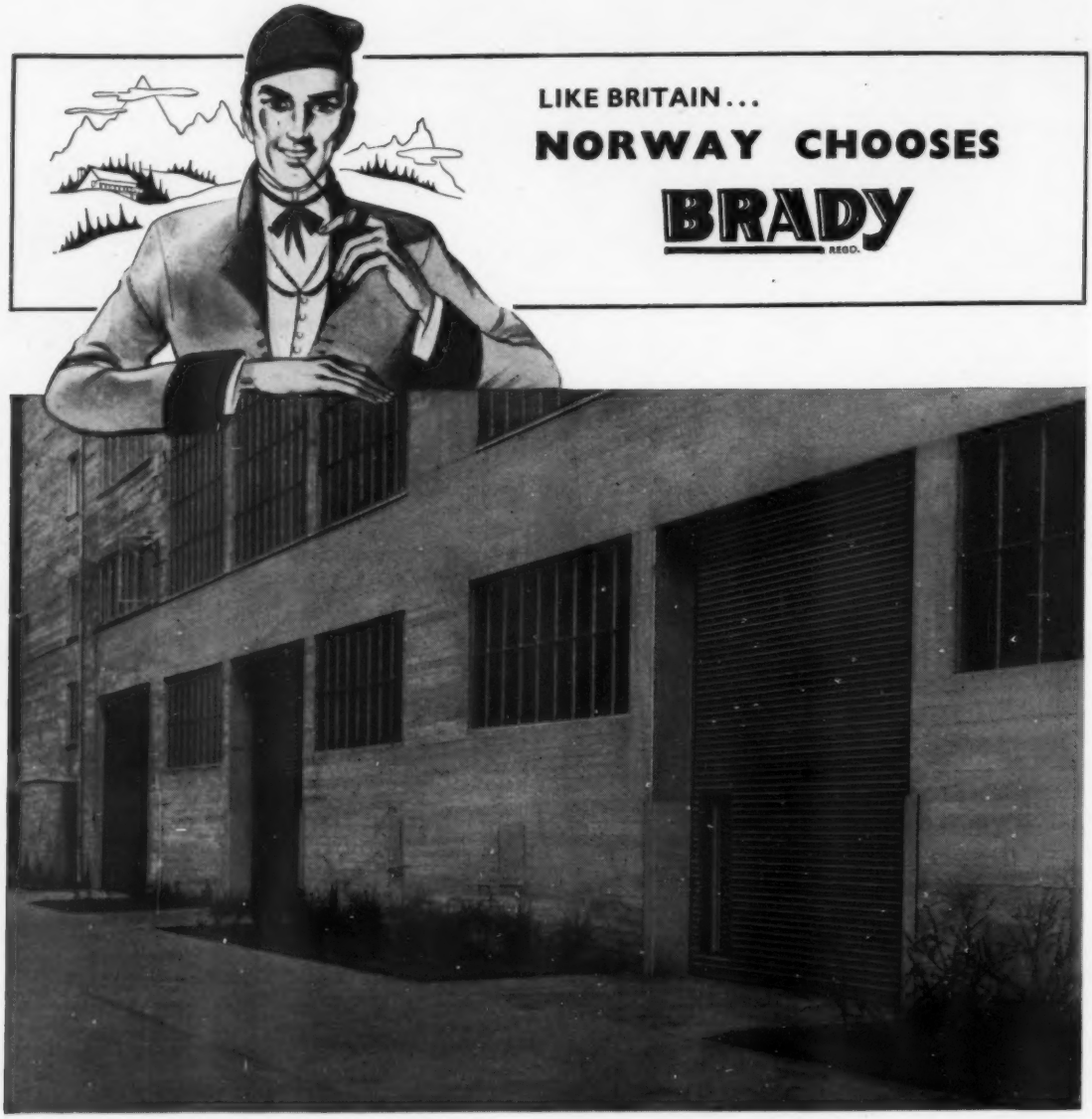

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That's why Westinghouse has always been the first to improve its own products for the generation and distribution of electrical power. A typical example is the Type GM Oil Circuit Breaker introduced a few years ago. This De-ion breaker saved as much as 20% in floor space, 7% in height, 52% in weight and 56% on oil required for previous breakers. Now, making this good breaker even better, Westinghouse has produced the new Type GW Oil Circuit Breaker.

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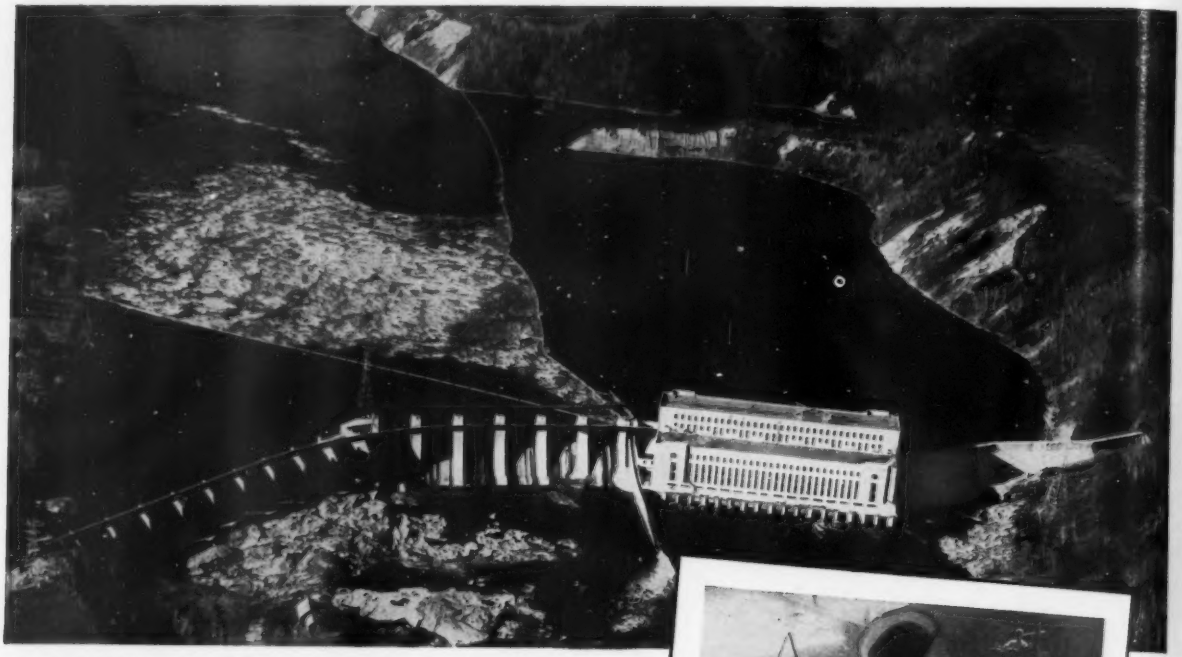
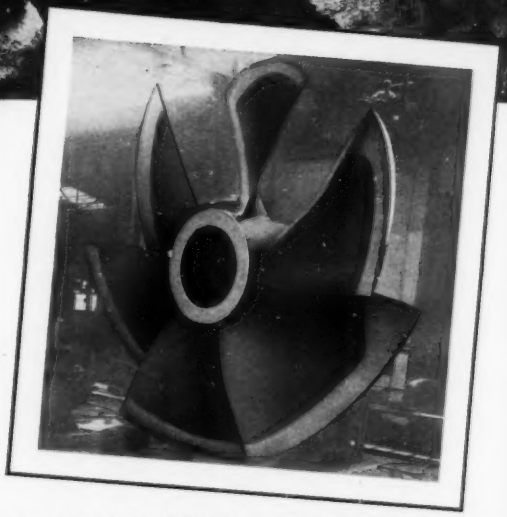


The La Gabelle plant of the Shawinigan Water and Power Company, containing five Dominion fixed blade propeller turbines of 35,000 H.P. each, at 120 R.P.M. under a head of 60 feet.



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The fixed blade propeller turbine is as simple in construction and operation as the lower speed Francis turbine. It does not require the complicated mechanism and governor control, in the rotating element, of the adjustable blade propeller turbine. Nevertheless, the fixed blade propeller turbine, in many installations, utilizes the available hydraulic power as effectively as the more expensive type.

Since 1921 Dominion Engineering have received orders for 89 fixed blade propeller turbines with a total rated capacity of 1,244,245 H.P., and are now manufacturing 14 units of this type, with throat diameter of 205". Eight units, of 21,000 H.P. each, at 94.7 R.P.M. under a head of 40 ft. are for the Chenaux Development of Hydro-Electric Power Commission of Ontario, and six units of 19,000 H.P. each, at 94.7 R.P.M. under a head of 37 ft. are for the Pine Falls Development of Department of Mines & Natural Resources, Province of Manitoba.

This background of experience, combined with a systematic research programme in our own laboratory, is at your service. We confidently invite your enquiries.

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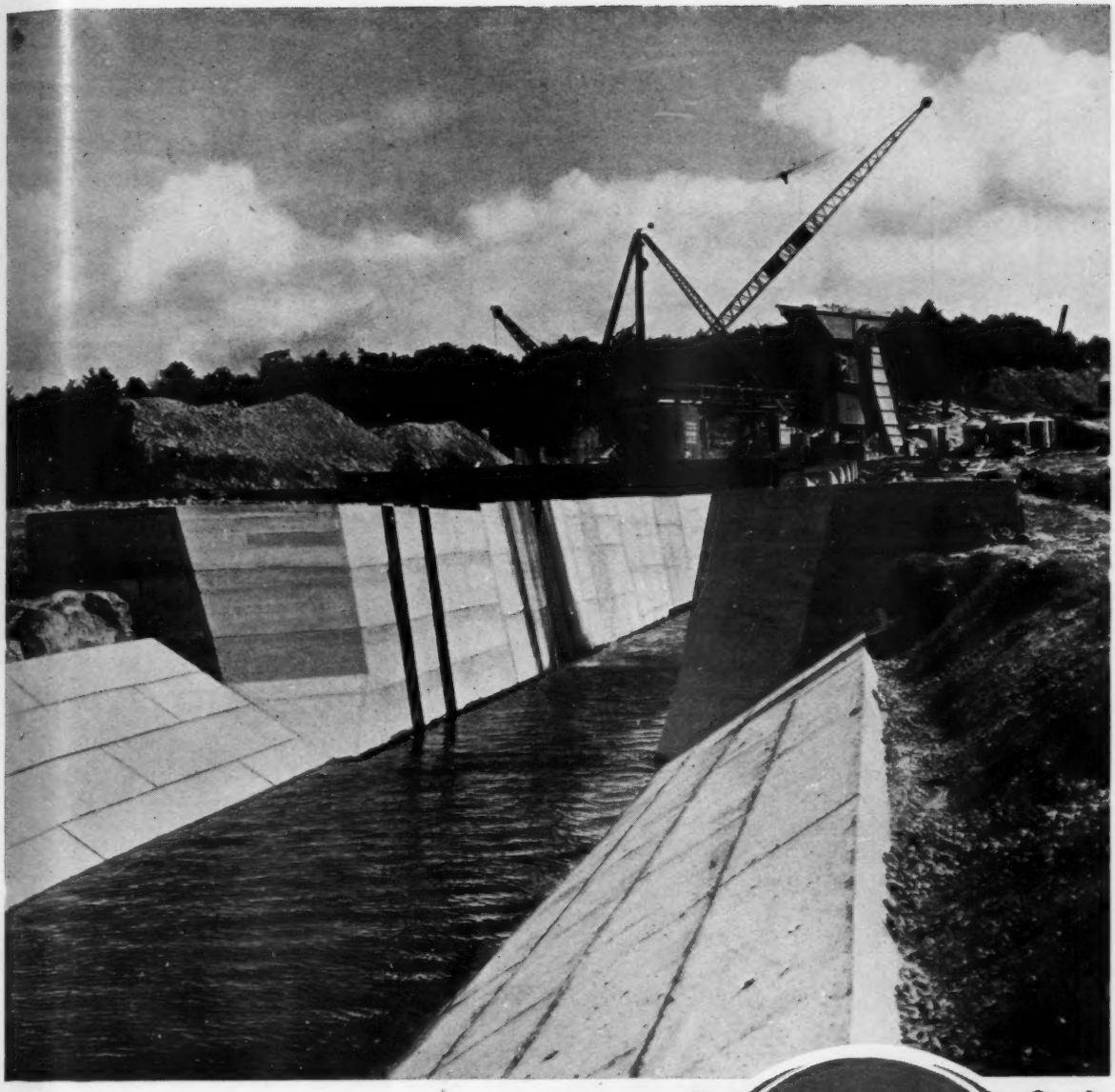

Work on the diversion tunnel and channel at the Weir Wood Reservoir Contract, which is one of the water conservation schemes being carried out by the Company

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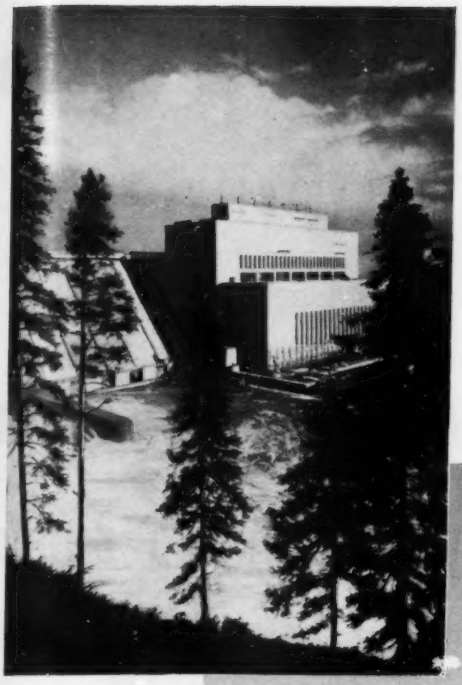
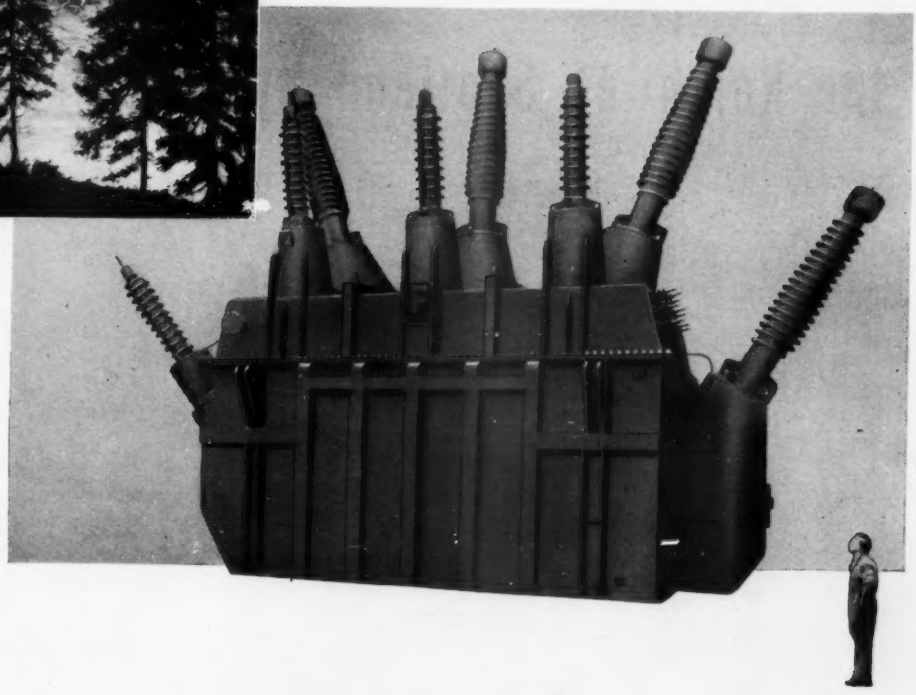


The Pyhäkoski Power Station, total output 108 MW, the largest in the current water-power programme of Finland.

A 3-Phase 230 kV FERRANTI TRANSFORMER for Water Power



This three-phase 230 kV Ferranti Transformer is one of five being installed at the Pyhäkoski Generating Station and Hikia Transforming Station of the Imatra Power Company, Finland.

They are the first three-phase 230 kV transformers to be ordered in Britain, and were adopted because of their advantages in cost and efficiency. Total weight of each transformer and cooling gear is 220 tons.

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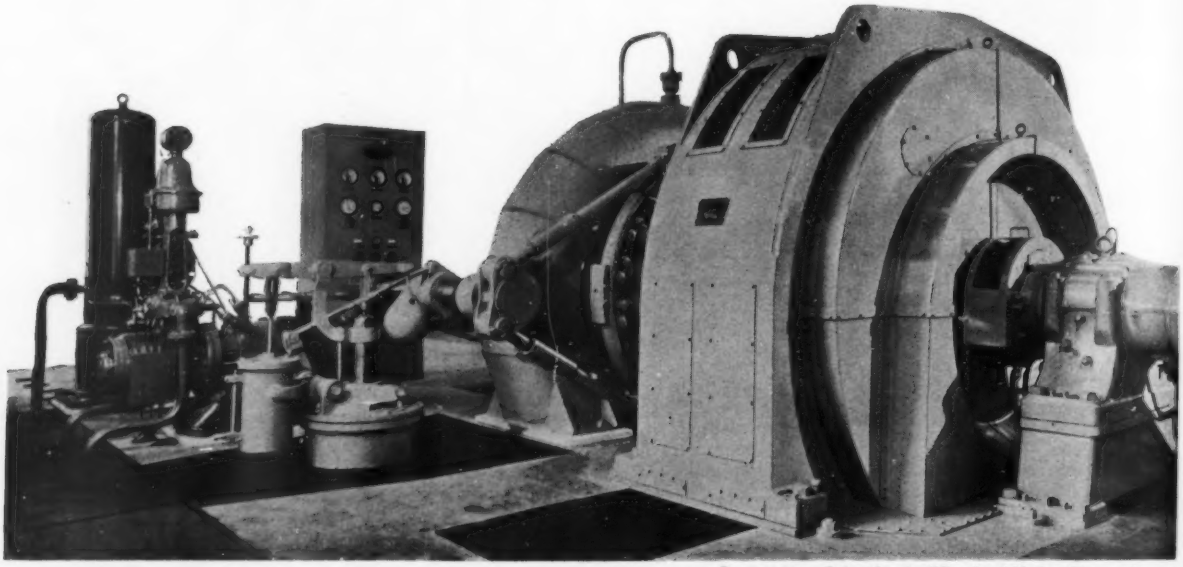

By courtesy of the North of Scotland Hydro-Electric Board

This power station contains 2 - 4250 b.h.p. "Harland-Morgan Smith" Francis Turbines driving 3529 kVA "Harland" Alternators—a fine example of hydraulic and electrical generating plant manufactured under one roof and erected at site by Harland specialist Engineers.

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WATER POWER

A technical journal devoted to the study of all aspects of Hydro-Electric Development

Evaluation

THE published statistics given in the various official summaries of world resources of water power disagree in many respects, but the majority of them have been reasonably unanimous in assuming that many particular rivers do not provide practicable sites for hydro-electric stations, for reasons either of inaccessibility (and consequent high cost of development and energy transmission), lack of sufficient fall and consequently ground area for impounded water, or for reasons of heavy seasonal fluctuation in flow.

It may be the case that the current rapid spread of power-system interconnection, which is now bringing power-generating units many thousands of miles apart into electrical juxtaposition, will cause a new evaluation to be made, in many cases where schemes had been abandoned years ago after an initial survey.

Another factor bearing on the matter which will have to be taken into account within the next decade is the harnessing of tidal power. In the past, this method of power generation has generally been considered uneconomic for the main reason that the output of a single large tidal station is available for so few hours in each day, and moreover, these hours continually vary with the tidal cycle. Thus, it was thought it would be necessary to build equivalent thermal plant, and to use the tidal energy only for fuel-saving purposes.

Increased interconnection will mean not only increased diversity of demand but also increased diversity between tidal cycles. When, for example, Great Britain is linked to the Continent by the Channel cable, in about five years' time, the disparity between the time of maximum tidal generation at the projected Severn barrage, and the equivalent time at the proposed Rance tidal scheme, will mean that firm power will be available for a much greater proportion of the twenty-four hours. If other schemes are brought in, perhaps on the Scandinavian coastline, tidal energy will always be available.

Even before this desirable state of affairs occurs, there is the possibility of employing tidal power entirely—or at any rate mainly—for pumping water into high-level reservoirs to even out seasonal fluctuation. From this point of view alone, such schemes could be extraordinarily useful in improving the regulation of difficult rivers, and in preventing droughts from interfering with power production.

Inaccessible water-power sites nowadays present fewer difficulties. Methods have been evolved for transporting stator, rotor and turbine components in pieces, to be assembled on site. Much experience has been gained in building labour camps and organising highly mechanised, rapid civil-engineering construction work. Above all, the transmission of the energy generated, along almost any distance, has become both technically practicable and economic.

The universality of large-scale transmission-line networks of an even greater capacity than those existing at present may also improve the situation regarding the harnessing of rivers with a gently inclined valley, where any barrage might cause severe flooding over wide areas if the flow of water were in any way restricted at such times. It has not been considered practicable or economic to embark on such schemes, because of the limited period during the year when the energy could be generated for local use; and hitherto the same economic arguments as for the tidal barrage have largely applied. But the energy contribution of a slow-flowing river, in terms of saving of coal, or perhaps in assisting in storage of water in other river systems, may well be found to be entirely justifiable if adequate transmission capacity is available.

It is, of course, possible that the production of power from nuclear fission will alter the economic picture regarding the use of water power, but nothing has yet been said, either in America or elsewhere, to indicate that nuclear power plants can be situated at *any* convenient point, near the load. For safety reasons, they are likely to have to be sited in remote areas where transmission charges will be high and will have to be added to the very large capital expenditure and overhead charges necessary for the refining

of the primary atomic fuel and its conversion into energy in the reactor. Consequently, it seems unlikely that there will ever be a time when the harnessing of all available sources of natural power will be abandoned in favour only of nuclear energy. The availability of suitable raw materials within the confines of a particular country's boundaries may also be a factor which will cause governments to insure their power supplies by a judicious balance between atomic energy and water power.

The remaining transmission problems are rapidly being solved. It is perhaps too early to say yet that transmission experts can carry any amount of energy from any one place on the world's surface to any other, but this state of affairs is in sight. The submarine cable problem is in the process of being solved by the aid of high-voltage direct-current cables, and the next ten years should see both the Gotland-Sweden link established and also much experimental work carried out in regard to direct-current operation of the cross-Channel cable. Other high-voltage direct-current schemes are on the brink of realisation. Lengthy overhead transmission projects offer little difficulty, in the light of the Swedish 380 kV lines extending for 600 miles, and the growing use of series capacitors for increasing transmission capacity and obviation of the stability difficulties encountered when great distances are considered.

Interconnection, by itself, does not create new power resources, but not only does it make the best use possible of existing means of power generation, but also it alters the economic balance sheet for new and hitherto impracticable hydro-electric projects.

Colonial Engineering Conference

THE series of conferences on colonial engineering organised by the Institution of Civil Engineers was intended primarily for engineers engaged in the Colonial Service and those concerned with similar work overseas. The third conference in this series has been held in London recently, seven papers being presented. Water resources of Southern Rhodesia and their development were described by Mr. E. H. Haviland, who outlined the stages in the development of the Irrigation Branch of the Agricultural Department which was responsible for all water supply installations on Government stations. The use of water from the river Zambesi must be dealt with separately, he said, since it was the concern of a number of countries. Utilisation of water from the river bordering the Colony was likely to be controlled to a large extent by the power potential of the river but the development of power would not prevent some use of the water for irrigation purposes in the Zambesi valley. The use of the Zambesi water elsewhere was likely to be confined to purposes other than irrigation because of the high cost of pumping.

The average annual discharge of the river at Victoria Falls was about 25·4 million acre feet, increasing at the Kariba Gorge to 33·7 million acre feet. Should the Kariba power scheme, which was planned to develop 1,000 MW and would involve the construction of a dam to store about 84 million acre feet, be proceeded with, then the use by Southern Rhodesia of Zambesi water above that Gorge would almost certainly be precluded, except for a small abstraction, although a portion at least of the discharge of 30,000 cusecs from the dam would be available for use in the valley below.

The reasons for the methods of proceeding with the development of hydro-electric power in Uganda were outlined by Messrs. C. R. Westlake and T. A. Lyell Paton, most of whose paper dealt with the economics of the Owen Falls scheme and some of the difficulties involved in the formulation of tariffs for the undertakings to be supplied.

Alberta Power Commission

THE Report of the Alberta Power Commission for the year ended December 31, 1951, is the first of a new series designed to provide up-to-date information on technical progress. It outlines the state of power development in the Province before the Commission was constituted in 1944 and gives details of progress made since that time. The interdependence of water-control and hydro-electric power problems is stressed, and the provision of adequate reservoirs to compensate for the extreme seasonal variations in flow is regarded as of prime importance. Earlier surveys on headwater storage problems on the North Saskatchewan, Clear Water and Red Deer Rivers have been reviewed in the light of later knowledge, and a large number of water-power investigations have been carried out. The Spray River project is in course of completion, and detailed studies have been made, amongst others, of the Bow River and Athabaska River drainage basins.

Some 13,000 farms have been connected during the past five years, and it is expected that several thousand more will be connected each year for several years to come.

Reference is also made to steam and natural-gas developments.

Power for the Gaspé Peninsula

THE Quebec Hydro-Electric Commission has announced a $100 million project to provide power for the whole of the Gaspé Peninsula, which forms the southern flank of the St. Lawrence estuary. The development will be on the Bersimis River, which flows into the St. Lawrence from the north-west about 30 miles west of Baie Comeau, and the power will be taken to the peninsula by submarine cables. The St. Lawrence is 40 miles wide at this point. A new town is to be built as part of the project, which is expected to be completed in 1956.

World Power Conference Brazil Meeting

A SECTIONAL meeting of the World Power Conference is to be held at or near Rio de Janeiro from July 25 to August 8, 1954, and the topics to be discussed will centre round the special energy problems of the tropical and subtropical countries. The technical programme will be divided into five sections: (1) Planning of the electric power industry, (2) Uses of electric power, (3) Power installations in tropical and subtropical regions, (4) Wind power, and (5) International hydro-electric developments. Hydro-electric matters will be well to the fore, as in addition to the fifth section, section 1 will discuss the thermal power station as the complement to hydro-electric developments, section 3 the influence of tropical con-

ditions on hydro-electric plants, and section 4 the use of wind power in association with thermal or hydro-electric plants.

The annual report for 1951 of the British National Committee has now been published, and among other matters refers briefly to the work of the International Commission on Large Dams and to the sectional meeting in India in 1951.

Inauguration at La Cave

ALTHOUGH the original plans for the La Cave project, on the Ottawa River near Mattawa, envisaged the first three 32,000 h.p. hydro-electric units being commissioned late in 1951, it was not until this summer that the Otto Holden development (as the station will be known after the Ontario Hydro Electric Power Commission's Assistant Manager in charge of Engineering) was officially inaugurated, with two of the three sets. High water conditions on the Ottawa River had delayed constructional work. The station will have an ultimate capacity of 256,000 h.p. and has involved the construction of a dam 2,500 ft. long to give a head of 81 ft. The resulting lake will be about 30 miles long and half a mile wide.

Burdekin River Scheme

THE Burdekin River Authority, which was constituted by the Queensland Government in 1950, has issued a report giving its detailed proposals for this comprehensive project. The purpose of the scheme is threefold: to conserve water for irrigation, to generate power, and to mitigate flooding. A dam is to be built just above the Burdekin Falls, 99 miles from the mouth of the river, supplying extensive irrigation works as well as a power station, and a diversion dam will be placed 20 miles downstream. It is proposed in the first instance to take the main dam to an intermediate height—probably 75 ft.—and to raise it later to an ultimate height of 150 ft. It will then provide a storage capacity of 6,334,000 acre ft., which will be nearly 50 per cent. greater than the combined storage of the Snowy Mountains scheme, and will supply 5,400 acre ft. per day during the worst drought period. It will be a mass-concrete gravity structure, 3,040 ft. long at crest level and involving 1,270,000 cu. yards of concrete. The initial scheme contemplates the installation of 30,000 kW of generating capacity, giving 10,000 kW of firm power at 50 per cent. load factor. The final scheme will ensure the firm generation of 80,000 kW at 50 per cent. load factor and will irrigate at least 350,000 acres each year without restriction.

Seyhan Dam Project

A LOAN of $25·2 million has been made by the International Bank for Reconstruction and Development to the Republic of Turkey to assist in developing the Adana Plain, a productive agricultural and industrial area in south-central Turkey. A multi-purpose dam is to be built on the Seyhan River for flood control, irrigation and power, and these works are expected to be completed by 1956. According to the British Chamber of Commerce of Turkey the ultimate project covers the building of flood control levees along the Seyhan, Berdan and Ceyhan Rivers, collection channels at the foothills of the Taurus Mountains, an irrigation network, and further power facilities. The entire programme will cost the equivalent of $67 million and will not be completed before 1961.

Gavins Point Dam Commenced

WORK has now started on a multi-purpose project at Gavins Point with a hydro-electric capacity of 100,000 kW. It forms part of President Truman's new 3·9 million kW Defence Power Programme. The cost of the scheme is $44,900,000, and it is scheduled to be completed in 1956. The generating plant will consist of three 54,000 h.p. turbines which will be installed on the western side of the river just over the Nebraska State boundary.

Mexican Progress

THE total capacity of Mexico's hydro and thermal electric plant is now in the neighbourhood of 2 million kW, according to the Department of Hydraulic Resources and the Federal Electrical Commission. Statistics issued by the two agencies show that at September last there was a total installation of 1,400,379 kW in 1,828 plants owned by 1,531 companies. Of this figure, 705,395 kW was hydro-electric, 503,901 kW steam and the remainder oil-engine driven. Twenty-two new plants are now in various stages of construction.

New Zealand Priority

ON June 18 the New Zealand Government announced that restrictions on the use of electric power in the Northern Island can be expected for some years. In the meantime, the Government has decided that the development of hydro-electric power will be continued as a first priority, everything possible being done to hasten all schemes for harnessing water power. A 100,000 kW thermal station is also being planned.

Ibex versus Hydro Power

WE have commented in these columns on more than one occasion on the irrational attitude sometimes adopted by those who obstruct hydro-electric planners on amenity grounds. We have suggested that beauty not only lies in the eye of the beholder but also appears to be found wherever it is desired to construct a hydro plant. Now comes the news of a new type of objection. The last truly indigenous herd of Ibex appear to have their being in the Parco Nazionale del Gran Paradiso in the Graian Alps, near the famous St. Bernhard Pass, in the extreme north-west of Italy. New hydro-electric sources are known to be few in number within Italian territory, and the suspension of work on a large reservoir in this Park means that at least three hydro-electric stations cannot be brought into commission.

We are not suggesting that the Ibex should be either exterminated or even inconvenienced, but we do feel that these innocent creatures, if they could be consulted, would be the last to object to a temporary inconvenience while new habitats in the neighbouring Alpine regions were discovered for their future well-being.

Fig. 18. Santa Giustina dam with the upper outlet discharging

Santa Giustina—II

A hydro-electric scheme on the River Noce in the province of Trento and recently completed by the Edison Company, one of the largest public supply companies in Northern Italy, contains a number of features of unusual interest.

THE pressure tunnel itself is 5·2 m. in diameter and 2050 m. long, and is capable of carrying a maximum flow of 66 cu. m. per sec., the pressure being equivalent to 90 m. of water at the dam and 107 m. at the turbine control valves. Sectional drawings to show the general arrangement of the access shaft, pressure tunnel, and welded penstock, the surge shaft, power house and the pressure tunnel for the tailrace are given in Fig. 28. The surge chamber is of special interest as it comprises not only the usual vertical shaft but also, in parallel with it, a helicoidal shaft, rectangular in plan, which ascends with in-

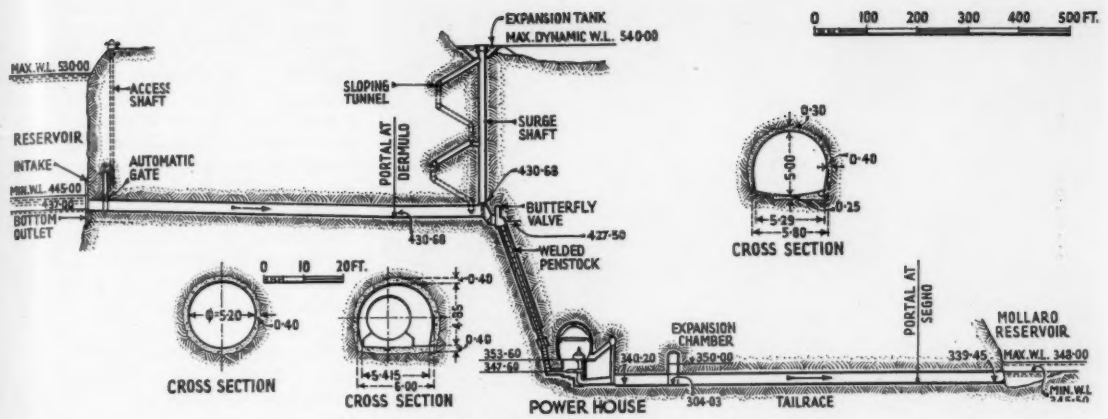

Fig. 19. Longitudinal section of the general scheme

Fig. 20. Penstock in course of erection

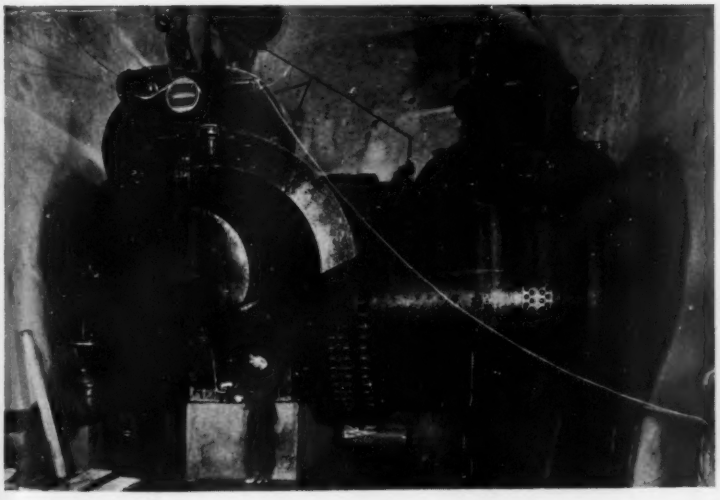

Fig. 21. Butterfly valve and anti-vacuum valve in course of erection

creasing inclination and hence variable horizontal area to ensure proper stability in the operation of the turbines. It should be understood that a vertical shaft to secure equivalent stability would have had to have been of such a large cross section that its construction would have been both difficult technically and prohibitive in cost. On the other hand the helicoidal tunnel was convenient to make and offered a horizontal cross-sectional area equivalent to a very large shaft. Both these surge chambers, Figs. 12 and 19, have a vertical height of 102 m. and discharge into a common expansion tank, Figs. 9 and 19, at the surface. Such is the effectiveness of these arrangements that it has been possible to dispense with relief valves at the turbines. Referring again to the schematic profile, Fig. 19, it will be seen that at the foot of the surge shaft there is an automatic butterfly valve, 3·6 m. in diameter, to control the flow into the steel penstock, which is freely supported in a steeply descending shaft leading to the power house. This penstock is 151 m. long, 3·7 m. in diameter at the top and tapers down to 3·5 m. in diameter at the point where the branches are taken off to the three turbines. The final branch to the No. 3 turbine carries a small-diameter extension to serve two auxiliary units, each comprising a horizontal Riva Francis turbine direct coupled to a 3,000 V 760 kVA alternator of Tecnomasio Italiano Brown Boveri manufacture.

The three main power units consist of Francis vertical-axis turbines manufactured by the Riva Company (S.p.A. Costru-

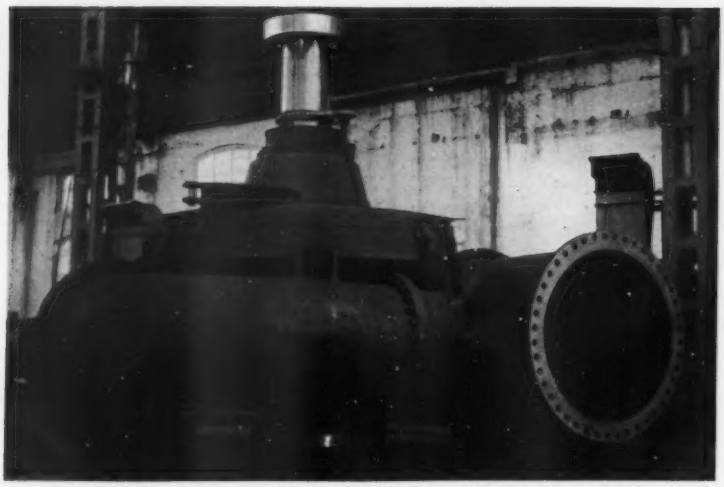

Fig. 22. Works view of one of the Riva 47,500 h.p. turbines

zioni Meccaniche Riva) of Milan, coupled to 41,000 kVA 10,000 V three-phase alternators from the works of Tecnomasio Italiano Brown Boveri, of Milan. It needs to be emphasised that these turbines are called upon to operate under very variable conditions, the heads ranging between 184 and 95 m. and the discharge rates between 22·2 and 15·9 cu. m. per sec. The turbine runners are 2,000 mm. in diameter and develop a maximum of 47,500 h.p. They have been designed to operate at alternative speeds of 315 and 375 r.p.m. representing power generation at 42 and 50 cycles respectively. Governing gear consists of tacheo-accelerometer type equipment with an oil accumulating tank and air vessel, the gate mechanism of the turbine being actuated by two differential servomotors. Between each of the 1,800 mm. diameter Riva rotary valves and the corresponding final branches (2,200 mm. diameter) of the distributing main, a venturi tube is interpolated to permit a continuous record of the water flow to be obtained. Riva also supplied the thrust bearings which are of the oscillating shoe type and designed to take up a thrust of 200 tons. They are mounted on the upper cross beam of the alternators.

The generator leads are taken through ascending passageways to a gallery parallel to the main axis of the power house and are then conducted up a vertical 160 m. shaft divided into cells to minimise damages from possible short-circuits. This shaft leads direct to the surface. Here are situated the control room (Fig. 33), a bank of four 70,000 kVA transformers and the high-tension switching station. A view of two of the transformers is given in Fig. 30; they are of Italian Brown Boveri manufacture and are provided with four windings, two of which are at generator voltage, one at 150,000 V and one at 240,000 V. A view of the 150,000 V switching station with the control room in the background is given in Fig. 32.

The circuit breakers for the 150 and 240 kV service voltages are of Scarpa & Magnano manufacture and introduce certain rather original features, notably adoption of several pairs of contacts in

Fig. 23. Power house during construction, showing the false roof being erected

series, with circular movement on a horizontal plan, each contact having a separate arc-extinction chamber and being actuated by the twisting of a single vertical rod. By reason of this design and the low value of mechanical inertia of the moving parts, it is possible to obtain high speeds of separation of the contacts and therefore a quick increase of dielectric strength in the contacts. The pressure built up by arcing in the extinction chamber is employed to produce a strong oil-blast transverse to the arc, so that deionisation of the gaps is rapid and the performance of the breaker is little affected by the rate of rise of recovery voltage.

The power is despatched by four 150,000 V and eight 240,000 V transmission lines, the control board having been built up by the Edison staff to their own design.

Fig. 24. Gallery for the main 10,000 V busbars

Fig. 25. Power house with false roof complete and main sets in course of erection

An annual output of 300 million kWh is confidently expected from this station, and what is of special importance to Italian economy is that the larger proportion (161 million kWh) of this output can be delivered during the winter months when, generally speaking, the total run-off is greatly diminished by the freezing of the snowfields. The output during the summer months is about 140 million kWh.

The power house, which has been excavated out of the solid rock, is 61·3 m. long and has an overall height of 17 m. from the level of the operating floor to the crown of the arched roof. A view taken during the constructional stages is reproduced in Fig. 29 which shows the method of excavation. A core of virgin rock is left *in situ* around which relatively narrow passageways are driven to accommodate the shuttering for the permanent concrete support lining. To ensure complete dryness and prevent any possibility of condensation, a false arch roof is inserted, springing from the crane runways at about 10·5 m. above floor level. The 185 ton electrically operated travelling crane which serves the station was supplied by Ceretti and Tanfani of Milan.

In keeping with Italian traditions a very fine finish has been given to the power house. The floors and walls are tesselated

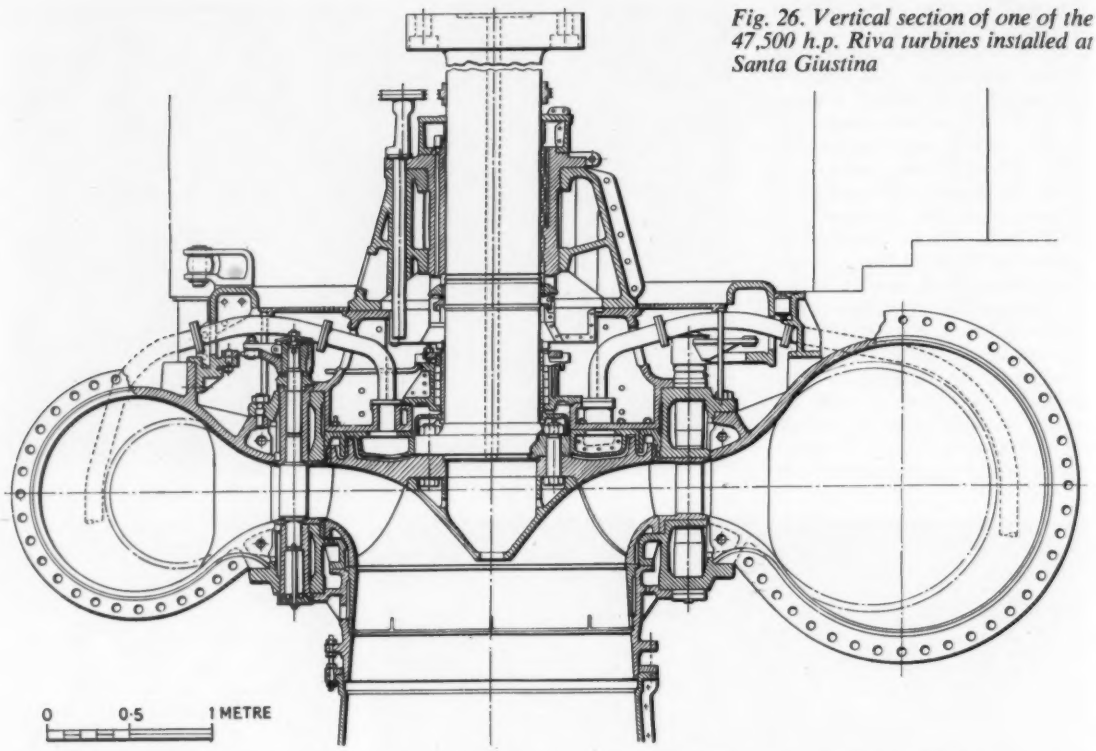

Fig. 26. Vertical section of one of the 47,500 h.p. Riva turbines installed at Santa Giustina

with small (about 1 in.) cream-coloured squares which are extremely hard and give a businesslike and yet exceedingly pleasing effect. The interior and exterior of the control buildings at the surface are similarly treated, and we were informed that this finish, which is very durable and requires practically no maintenance, is not, at any rate in Italy, unduly expensive.

Before leaving the power house it should perhaps be explained that the vertical shaft to the surface has other functions besides that of carrying the 10,000 V conductors. In addition, there is a lift and stairway compartment, an air duct for the ventilation of the

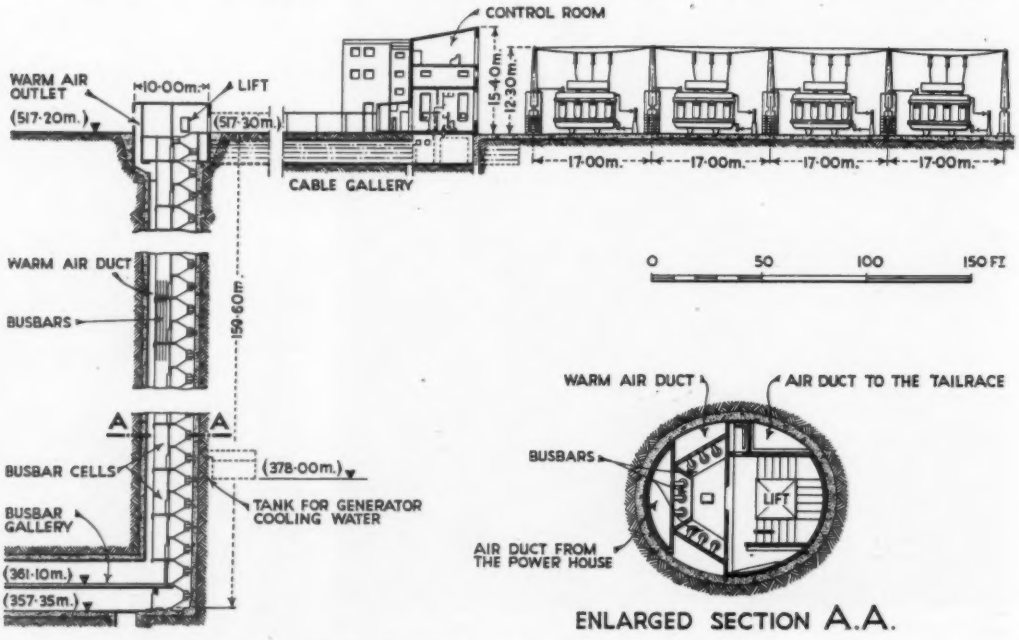

Fig. 27. Busbar shaft and transformer substation

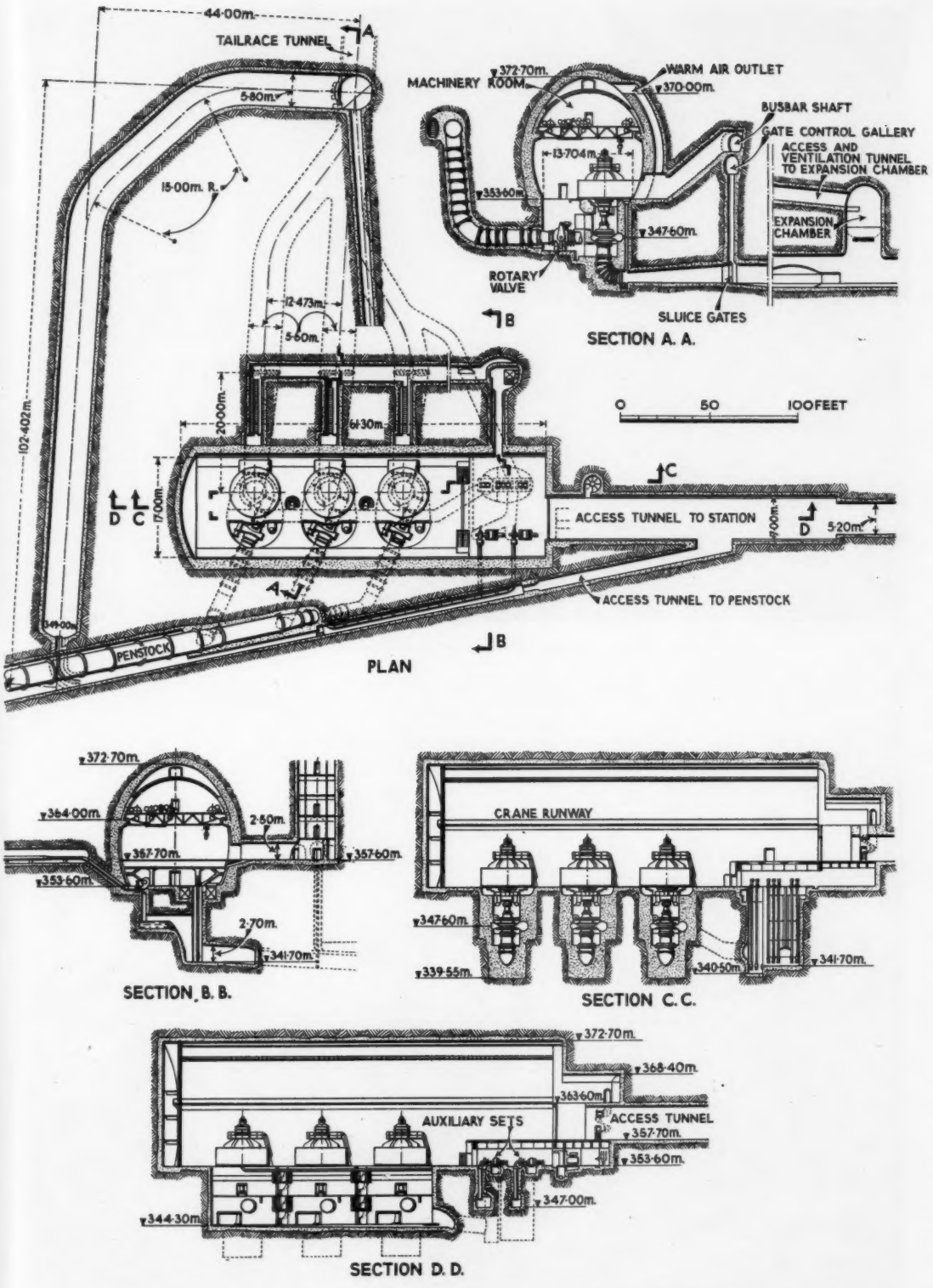

Fig. 28. Plan and various cross-sectional elevations of Santa Giustina power house

Fig. 29. Method of supporting the roof of the power house during excavation

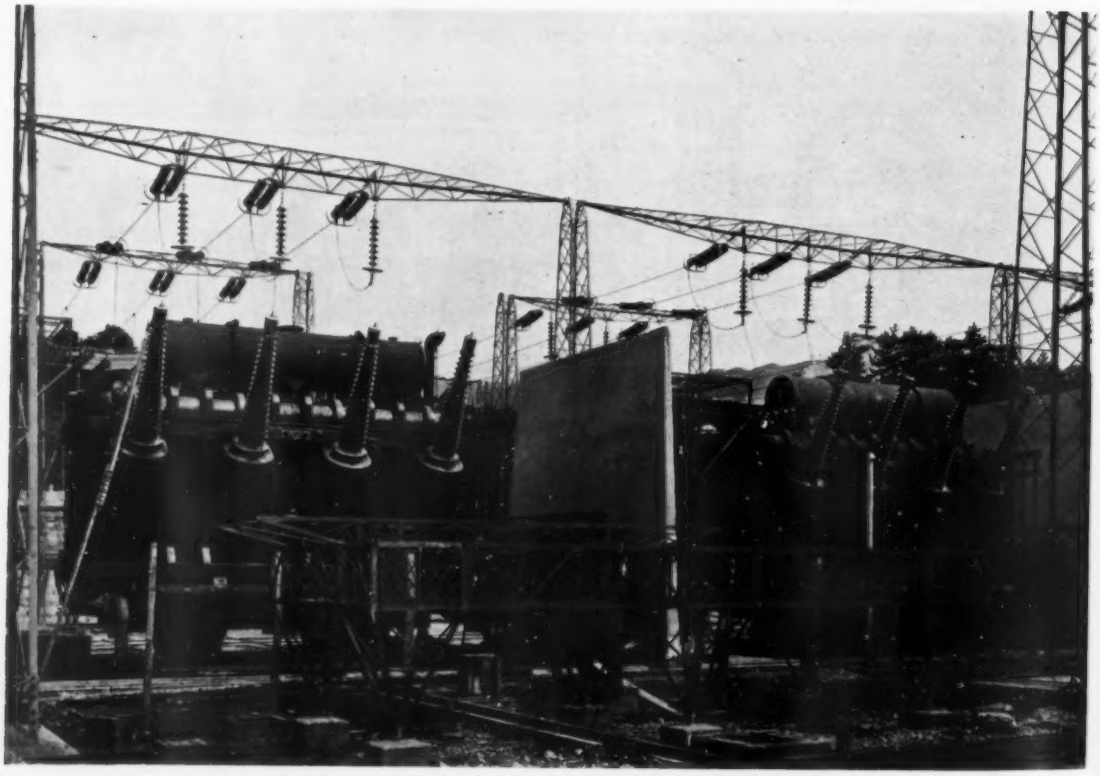

Fig. 30. Two of the Italian Brown Boveri 70,000 kVA transformers

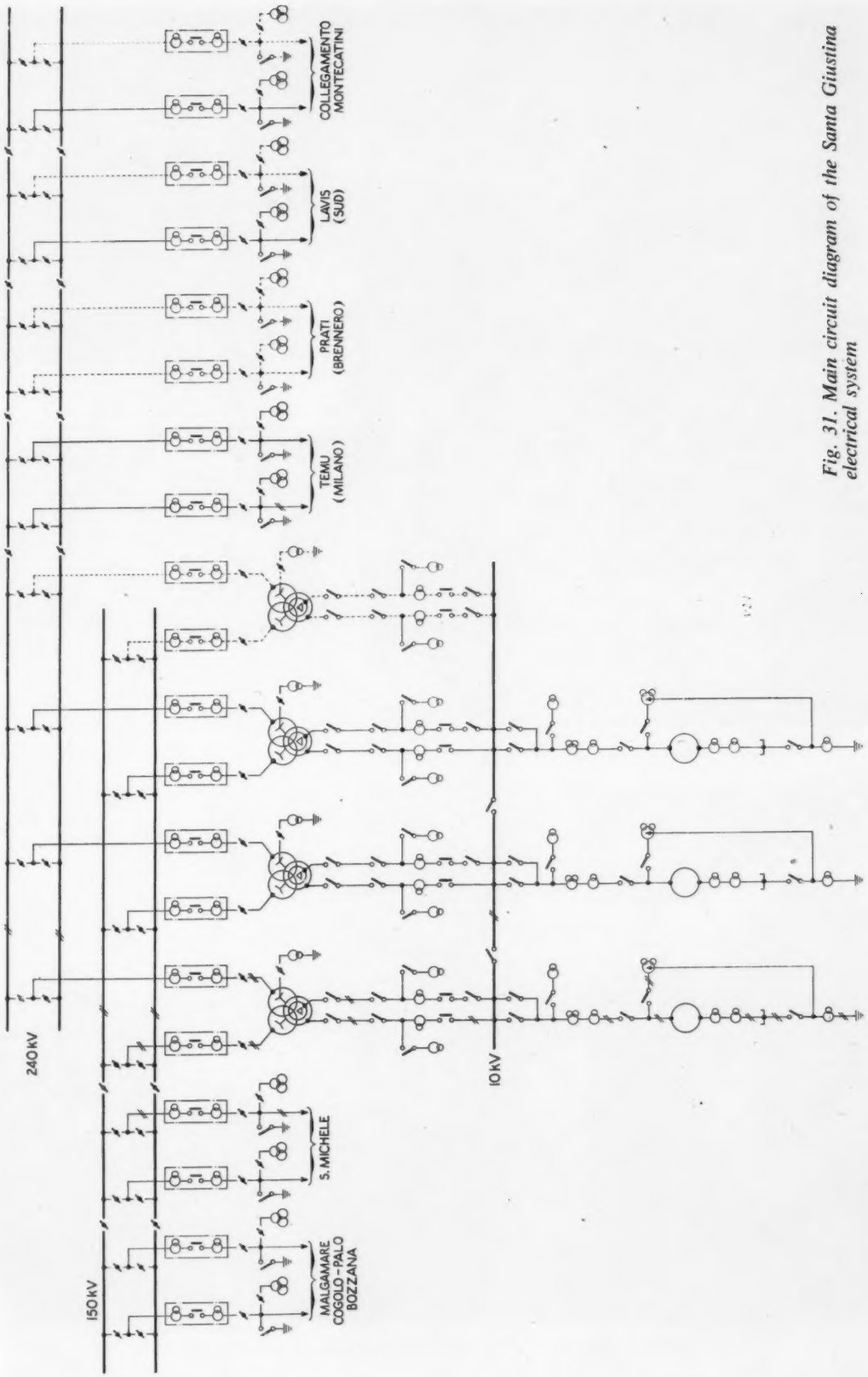

Fig. 31. Main circuit diagram of the Santa Giustina electrical system

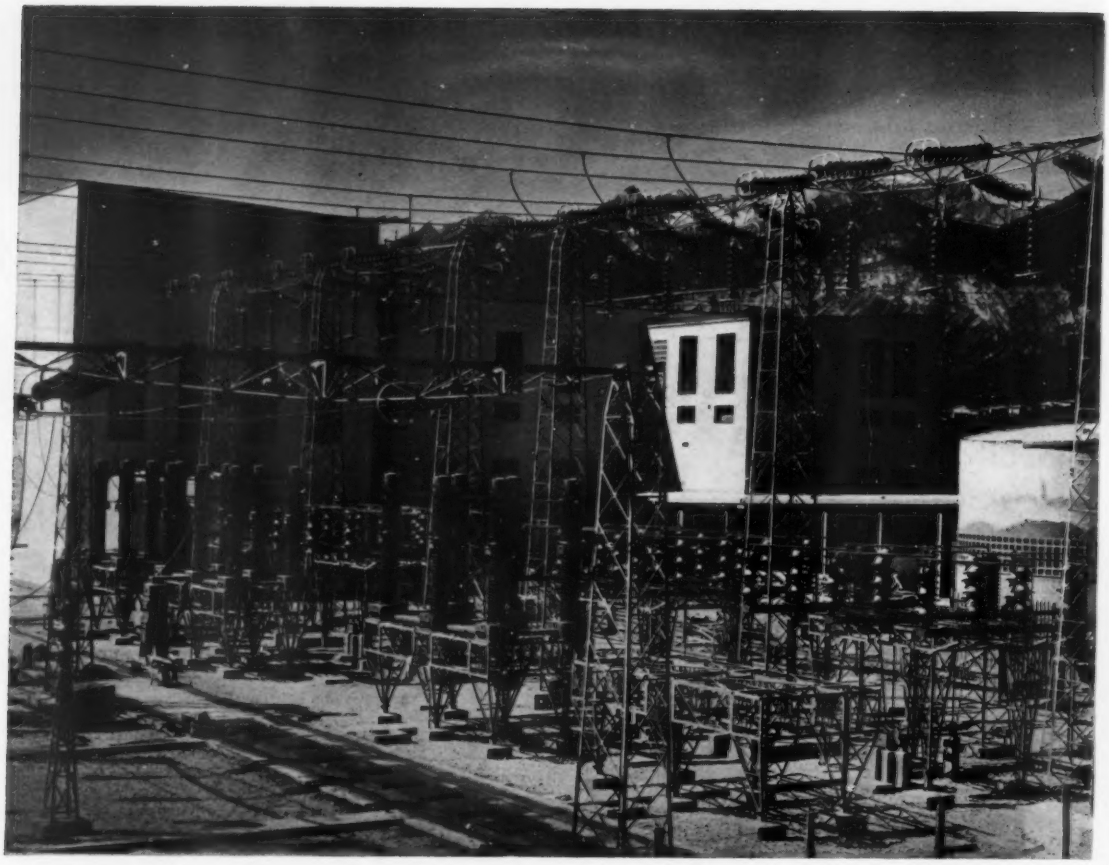

Fig. 32. Switching station containing Scarpa & Magnano circuit breakers for the 150 and 240 kV services

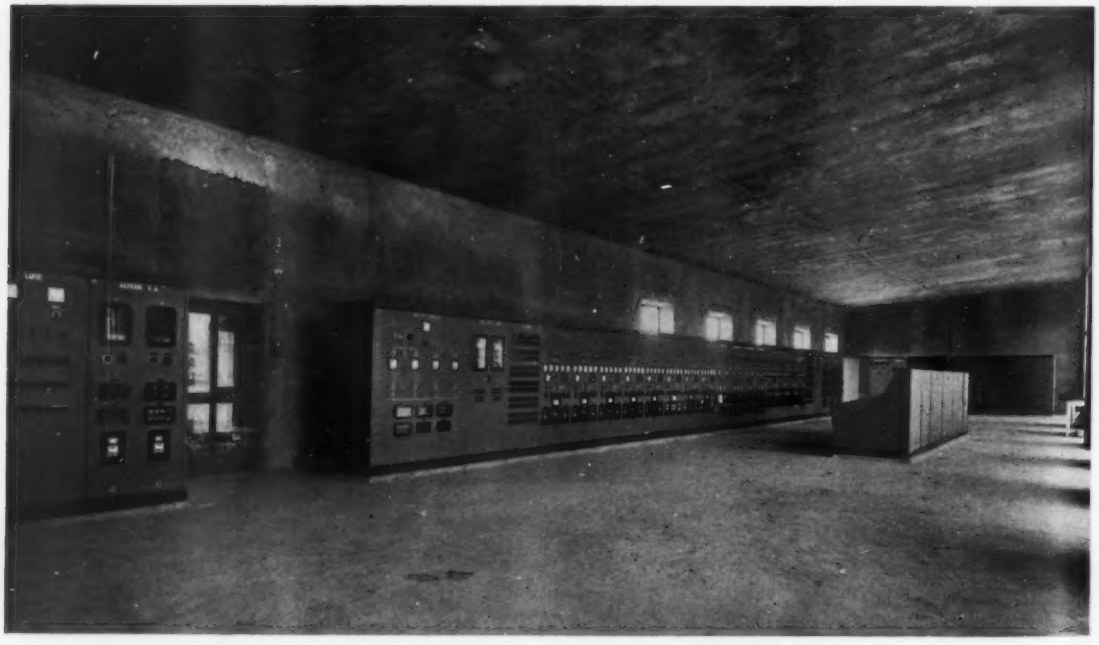

Fig. 33. The control room of Santa Giustina power station

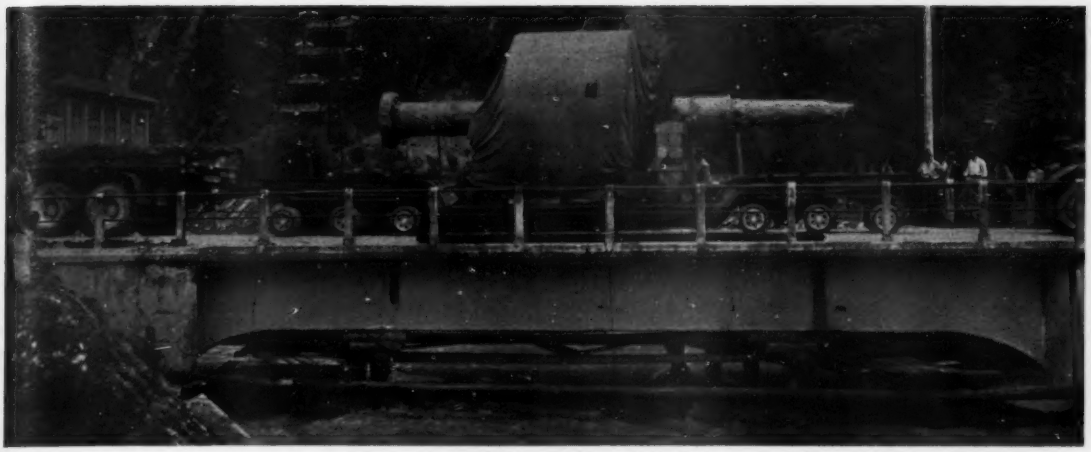

Fig. 34. The rotor of one of the alternators in course of transit to the station

Fig. 35. A view in the tailrace showing the termination of the draught tube

power house, as well as air ducts for the cooling of the generator leads and an air vent for the tailrace.

The tailrace is essentially a pressure tunnel as it is designed to discharge into the Mollaro reservoir at the minimum water level (O.D. 345·5 m.) whereas the maximum water level is 2·5 m. higher. In this way no loss of head is incurred between the Santa Giustina plant and the Mezzocorona station which is served by the Mollaro reservoir. The tunnel is concrete lined, is of horseshoe section (Fig. 35) and is 1,917 m. in length. To equalise the flow conditions an expansion chamber is provided near the upper end.

The entire development was designed and built directly by Edison Company under the general management of Dr. Ing. C. Marcello and the local supervision of Ing. A. Gervaso, while grouting at the dam site was carried out by the Firm Ing. Ponzani, according to plans prepared by Edison.

Acknowledgments

In concluding this brief description of the Santa Giustina dam and its associated power station, we are glad to acknowledge our obligation to Ing. Piero Ferrerio, the President of the Edison Group (Societa Edison) who so kindly afforded us facilities to inspect a number of the more important hydro-electric developments which are taking place in northern Italy. We are also indebted to Dr. Ing. Claudio Marcello and to Dr. Ing. Dolcetta for many personal kindnesses and their unstinted help in the collection and preparation of our data, and to Mr. Giovanola, the public relations officer of the Group, who accompanied us on our trip and who gallantly drove us through so many hundreds of kilometres of rain, floods, fogs, darkness, which, however, were happily interspersed with a few warm bursts of typical Italian sunshine.

Third Unit for Paulo Afonso

Companhia Hidro Eletrica do Sao Francisco has completed purchasing of power equipment for Paulo Afonzo, Brazil's largest postwar hydro-electric project, with an order for a third 60,000 kW waterwheel generating unit from Westinghouse Electric International Company. One of two previously ordered Westinghouse units is at the site awaiting installation, and delivery of the second is now under way.

Westinghouse is producing the generator at its East Pittsburgh, Pa., plant. The turbine and draught-tube gates are being built by Dominion Engineering Company, Montreal, Canada, while the head and tainter gates are being supplied by U.S. Steel Export Co., and S. Morgan Smith Company. The three generating units will be installed in an underground power house and fed through natural penstocks.

Westinghouse is also supplying all transformers and switchgear for the project.

Surge-Tank Stability

Dr. Charles Jaeger discusses the problem of the stability of surges in surge tanks in the light of the contribution by Prof. Escande in our June, 1952, issue.

IN recent years an increased interest has been shown in problems concerning the stability of surges in surge tanks. Some years ago, it might have been foretold that, owing to increased interconnection of generating stations over large transmission grids, the problems of stability of surge tanks would become of less importance. There is now a definite tendency to consider that owing to possible interruptions of the transmission lines, any large station may have to take over without warning and to act as the frequency controller for part of the grid, remaining isolated from other large control stations. Any major station working in such emergency conditions has to be stable on its own. On the other hand, any large surge tank even if small by comparison with other items such as a long tunnel or a large dam, is in itself a major construction of which the cost has to be scrutinised critically. Owing to these contrasting circumstances, the problems of surge-tank design and surge-tank stability have assumed renewed importance in recent years.

A convention of specialists was called at Padova in October 1947, by the Italian Consiglio Nazionale delle Ricerche (National Council for Research) and its subsidiary the Centro Veneto di Ricerche Idrauliche[13, 14, 15, 16] which aimed at investigating problems of surge-tank stability in relation to the stability of water-turbine governing. A second convention was held at Bologna in 1951. These conventions were completed and followed by a series of publications in Italy, France and Switzerland upon which it is impossible to comment here at full length. The main results of this important effort are the general confirmation of the law of Thoma (1911), regarding the minimum area necessary to ensure damped oscillations, with many important improvements and additions to this formula. The most interesting result of modern research work is to show the interconnection between turbine regulation through conventional governors and the stability of surges. Several new devices were proposed, or are under consideration, to stabilise tank surges and governor oscillations. A list of some of the most recent publications on surge-tank stability is to be found at the end of this paper.

The purpose of this present article is to comment on several important points arising from a recent publication by Prof. Escande in the Annales de L'Académie des Sciences January 14 and 21 1952. (See WATER POWER June 1952)[27]. The analysis by Prof. Escande shows that the rule established by Thoma still holds good for the case of throttled surge tanks (tanks with restricted orifice). It was found that when the surge tank area is smaller than the minimum area given by the formula of Thoma, the surges in a throttled tank will increase, but instead of growing indefinitely so as to become unstable, they will tend towards a definite limiting value which can be smaller or greater than the first initial oscillation. Some additional remarks on the analytical and graphical treatment by Escande are given below.

Stability of Large Oscillations

Nearly all the papers dealing with surge-tank stability assume that the oscillations have infinitely small amplitude. In most cases, the differentials of an order higher than two and the products of differential terms are neglected in the equations, which are simplified until analytical discussion becomes possible. This is done by Escande too.

Few authors are interested in what happens to the same equations with oscillations assumed to be of finite magnitude, the terms of higher order or higher degree then being no longer negligible in the equations.

Further enquiries[10, 17] have led to a formula yielding the factor $n^* > 1$ by which the area F_{Th} of Thoma has to be multiplied, if stability is to be achieved for large oscillations with a surge tank area F. It was found that:†

$$n^* = \frac{F}{F_{Th}} = \left(1 + 0{\cdot}48\,\frac{Z^*}{H + Z_o}\right) \quad \ldots\ldots\ldots (1)$$

† The letters used here are those introduced by Calame and Gaden in their classical treatise on surge tanks and in Escande's paper.

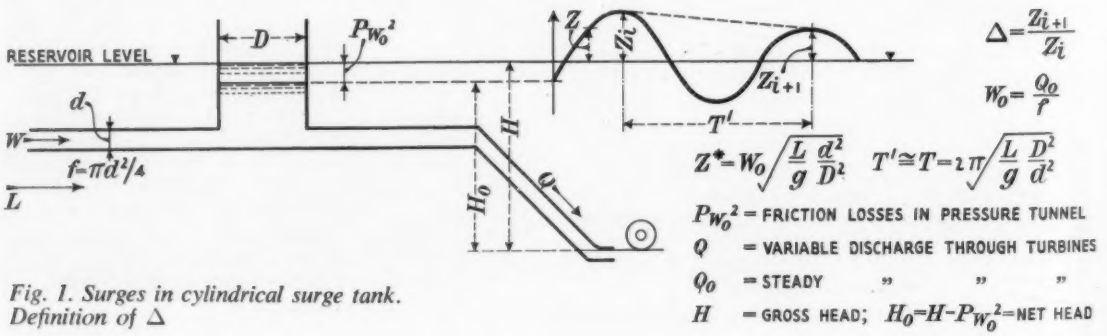

Fig. 1. Surges in cylindrical surge tank. Definition of Δ

In this formula, $Z^* = W_o\sqrt{\frac{L}{g}\frac{f}{F}}$ is the well-known value for the amplitude of oscillations when friction losses in the pressure tunnel are neglected. f is the cross-sectional area of the pressure tunnel (length $= L$), and $W_o = Q_o/f$ if Q_o is the steady discharge. H is the gross head Z_o (negative) the total friction loss in the tunnel. The validity of this formula has been confirmed by many direct step-by-step calculations.

Scimemi[15] points out that he found in some cases an increased stability when the surges are large, by comparison with the stability condition for small surges. The explanation of this fact is on the lines of the remarks by Prof. Escande for the more rapid damping of surges in throttled surge tanks. Both the formula (1) and the direct step-by-step calculations neglect the additional bend and turbulence losses occurring at the point where the surge tank is inserted in the pressure conduit. These losses are equivalent to those produced by the throttling of the water when passing through the restricted orifice of a surge tank. These losses are proportional to the square of the velocity $v = \frac{dZ}{dt}$ of the water rising in the tank and the mathematical treatment is similar to that for throttled surge tanks.

If the station is not a low-head plant, the influence of the corrective term $Z^*/(H + Z_o)$ in equation (1) may be concealed by the increased losses at the base of the surge tank. In cases where the head is low and the orifice losses negligible, the full effect of the corrective term may have to be considered.

An accurate estimate of the losses at the insertion point of a surge tank may be difficult unless special model tests of this arrangement are made. Such tests were carried out for the surge tank of Innertkirchen and the results of the tests with air were compared with the results of tests with water. If the right values for these supplementary losses are introduced in a step-by-step calculation[17], the decrement Δ (see Fig. 1) of the curve of oscillation will show the effectiveness of these additional losses for large oscillations.

Stability of Oscillations in throttled Surge Tanks

It has already been pointed out elsewhere[17] that further research work would probably show that for small surge oscillations in throttled surge tanks the formula of Thoma would be found valid. The research work done by Escande entirely confirms this point of view, as it proves that when the area is smaller than the limit given by Thoma, the small unstable oscillations are converted into larger stable ones, the constant amplitude of which is no longer negligible. The designer of modern surge tanks is bound to consider very carefully the possibility that resonance of surge oscillations[24] may occur when turbines are thrown on and off load, or off and on again at intervals of one or a few minutes. These alternate opening and closing movements of the gates may produce surges of greater magnitude than calculated usually, when considering the cases of throwing full load off, or taking full load on.

Let us suppose that a throttled surge tank has been designed for rapid damping of small oscillations. Interference by large oscillations may be regarded as an exceptional emergency case and treated as such. If the same surge tank is designed with an area smaller than that given by the formula of Thoma, any small oscillation will build up into a system of larger stable ones. Possible interference by large oscillations is liable to occur at any time and will actually occur reasonably often. The design of the whole surge tank may then have to be altered, because of the liability to these cases of resonance, and the economic benefit to be derived from a smaller surge-tank area may be denied by the larger surges.

Stability of Differential Surge Tanks

The differential surge tank (see Figs. 2 and 3) is characterised by an inner riser (area F_2) inserted inside the larger chamber (area F_1). The inner riser is provided at its base with a restricted orifice, which throttles the water entering the surge tank proper. Let $r_o V^2$ be the relative value of the orifice losses for full discharge. The surge will certainly depend upon F_1, F_2, r_o and p_o (relative value of the friction losses).

No theory of the stability conditions for differential surge tanks has yet been established, but it can be shown that the theory of the ordinary throttled tank provides the key to part of the theory for throttled surge tanks.

We shall first distinguish between two types of differential surge tank (Fig. 3).

In some cases, where the orifice at the base of the inner riser is large (r_o small), the differential surge tank behaves as an ordinary throttled surge tank. There is no—or only negligible—spilling over the inner riser (see Fig. 2), the maximum surge being identical to the surge in a throttled surge tank. In

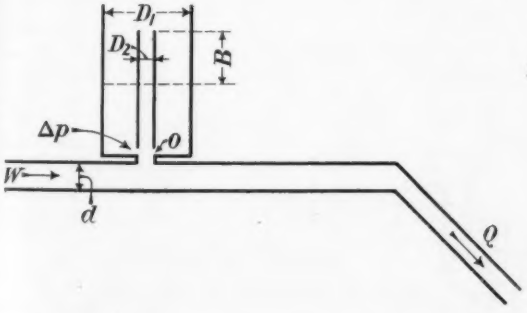

Fig. 2. Differential surge tank. Δp = pressure loss through restricted orifice O

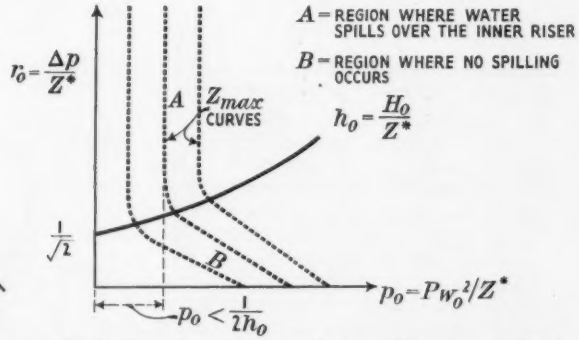

Fig. 3. Based on diagram 36 from Calame and Gaden "Théorie des chambres d'equilibre"

such a case the condition of Thoma refers to the area of the outer reservoir (F_1) and when this condition is not satisfied for small oscillations, a state of equilibrium may be reached with large oscillations occurring similar to those in throttled surge tanks with too small an area ($F<F_{Th}$). The final oscillations are given by the condition

$$\int_0^T r_o v^3 dt = \int_0^T r_1 v^2 dt$$

as introduced by Escande in his paper on throttled surge tanks. In the case here considered, the riser is merely a piezometric tube measuring the pressure in front of the orifice and its diameter is of little importance to the problem as long as no spilling occurs. The conditions for the downward surge should be identical to those for the upward surge, from which the minimum height of the tank may be calculated. Cases occur (when $2h_o p_o<1$), where this total height becomes greater than the first surges for closing and for opening, added together.

When the area of the restricted orifice is small and the throttling of the water passing into the outer chamber effective (r_o great), the water will reach the top of the inner riser and spill over during the first period of the rising surge. The limit of the up surge is then virtually equal to the height of the inner riser. A similar limit does not exist, however, for the downward surge. The diameter D_2 of the inner riser can no longer be neglected when considering the damping of the oscillations, and there is an obvious danger of unstable oscillations in the downward direction.

Full stability will certainly be obtained when the area F_2 of the inner riser satisfies the condition of Thoma. Differential surge tanks connected to high-head plants are likely to fulfil this condition and are stable. Others, especially those connected to low-head plants, may be unstable.

Differential surge tanks with small orifices, when connected to low-head power stations, must be specially checked as regards their stability. This can be done by a step-by-step calculation, or, alternatively, with a model to scale. The stability of the surges will depend, not only on F_1 and p_o but also on F_2 and r_o. A detailed exposition of the stability for differential surge tanks of the second type would be most involved.

In very large power stations, throttled and differential surge tanks are likely to be used in conjunction with other shafts (Fig. 4). These systems of surge tanks, where several shafts and chambers are connected to one or more pressure tunnels and which a few years ago were still an exception, tend to become a practical design in difficult cases. The theory of the stability of a series of surge tanks was developed some years ago for the case of shafts without restricted orifices. It seems unlikely that a theory could be developed for the more complicated cases and we have to rely here on the methods of step-by-step calculation[17].

Mention ought also to be made of the increasing importance which is being attached to proper governing, in order to increase the surge stability. The measurements of oscillations by Scimemi[15], in some large surge tanks of the Societa Adriatica di Elettricita, support the theory of Evangelisti[22], which tries to show the interconnection between surge oscillations and governing.

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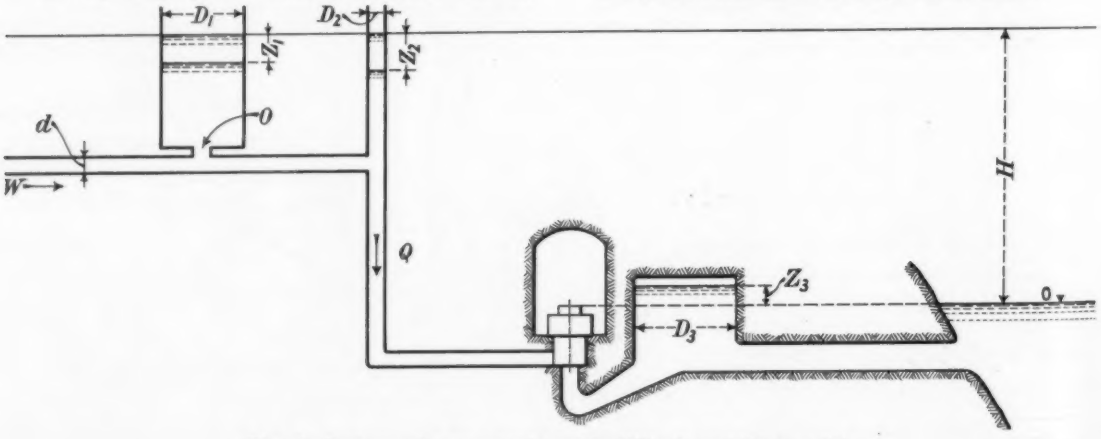

Fig. 4. System of surge tanks with difficult stability conditions

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Construction of the Dixence and Mauvoisin Plants

In 1944 the Swiss Federal Water Services studied the possibility of constructing water-power plants with seasonal storage in the Rhône Basin and particularly in Valais, and one of the most promising schemes was the extension of the existing Dixence plant, which was the property of the West Switzerland Power Company (E.O.S.), using a head of 1,750 m. According to this scheme all water from Zermatt to the Val d'Entremont was diverted to the new storage lake by means of a network of tunnels and a large number of pumping stations.

The programme of the West Switzerland Power Company had always envisaged the utilisation of the more important rivers in this area, but the concessions for the utilisation of this water were not purchased from the communes as it was believed that nobody would interfere in an area covered by the installations of the E.O.S.

In 1946, modified plans were adopted in which pumping plants were dispensed with. The entire scheme was divided into seven parts, each yielding one-seventh of the total power, to be constructed in seven years. The position became complicated, however, by the fact that the organisation concerned with the Mauvoisin plant acquired the concession of the Dranse, but after a few months of strained relationships it was recognised that the difficulty was not insuperable. The available water was either 400 million cu. m. at an altitude of 2,400 m. or 600 million cu. m. at an altitude of 2,000 m., so that with only one plant the choice would have had to be made between a loss of either 200 million cu. m. or of a 400 m. head. Thus the existence of two storage lakes at different levels was justified.

In the original Dixence proposal the dam would have needed 6,200,000 cu. m. of concrete, the added capacity would have been 810,000 kW and the added production 1,680 million kWh in winter and 280 million kWh in summer. In reality the summer capacity was 850 million kWh but the difference would have been used in pumping plants.

In the new project, the new Dixence dam will be 275 m. high and will be built at a lower level than the old dam, which will be submerged under 120 m. of water. As the tunnel of the existing Dixence plant cannot support the increased pressure, a new power house is to be erected at the foot of the dam. The new installed capacity, in four plants, is 720,000 kW, producing 1,600 million kWh in winter.

In the Bagnes Valley the Mauvoisin dam* will require 2 million cu. m. of concrete and will impound 160 million cu. m. of water. Thus, a cubic metre of concrete will retain only 80 cu. m. of water as against 4,180 cu. m. for the Etzel plant and an average of 350 cu. m. for storage lakes in the Western Alps. However, as the head is about 1,450 m., the kWh retained per cubic metre of concrete are about 275, which is an average value. (The figure for the Etzel plant is 4,000 kWh.) As the entire flow of the river cannot be stored economically, about 220 million kWh of summer energy, of low value, is to be produced. The annual capacity is 270,000 kW in two plants, and the production of winter energy 530 million kWh.

Thus, by distributing the available water over two storages at different levels, the area will produce 190,000 kW and 340 million kWh more than if the initial project with only one large lake had been proceeded with.

RENÉ P. CHAUVET.

Laloki River Catchment

In discussing hydro-electric potentialities in Papua and New Guinea on page 202 of our June issue we gave some figures regarding the estimated capital expenditure to produce 250,000 h.p. from the Laloki River. It is apparent that a typographical error occurred in our figures, as the Department of Works of the Commonwealth of Australia informs us that although no recent estimate has been prepared for this development, a scheme giving 250,000 h.p. at 50 per cent. load factor is likely to cost at least £15 million.

Concrete Compactor. In a brochure from Holman Brothers Limited, Camborne, a type of concrete compactor is described which has been designed for high-quality roadmaking. It consists of a series of pneumatic hammers mounted on a wooden batten and transmitting their blows to a steel channel flexibly secured to the batten and resting on the concrete. The compactor is claimed to be superior to the usual vibrated screed, as the full power of the hammers acts directly on the concrete. It can therefore compact mixes of a lower water-cement ratio, deal with larger areas in a shorter time, and compact more satisfactorily to a greater depth than the vibrated screed.

* See WATER POWER, January 1952, p. 39.

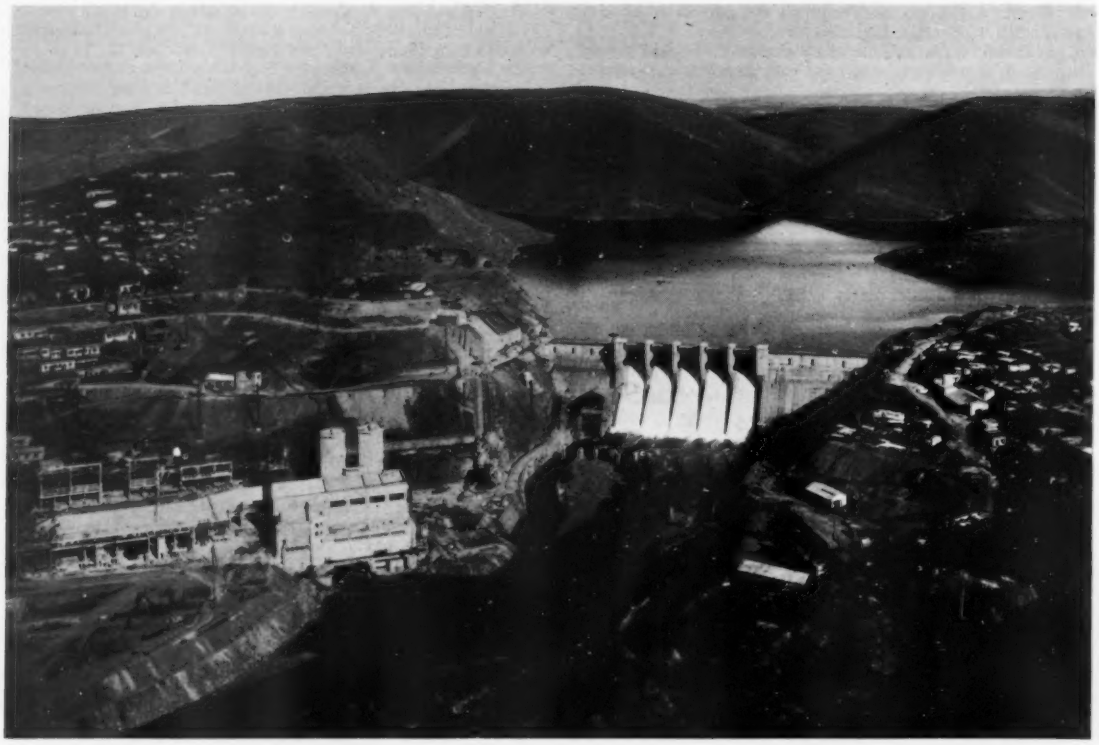


Fig. 1. One of the recently commissioned plants in Morocco at Im Fout. A general view of the dam, the station and the switching station

Hydro-Electric Developments in Morocco

Hydro-electric progress in Morocco may be said to have completed its second stage of development, and further projects are now under consideration.

HYDRO-ELECTRIC development has become of the utmost importance to Morocco's power economy, for in common with many other areas of the world the demand for electric energy has tended to outstrip the capacity of the generating plant. The following figures show the units generated in recent years:—

1930	...	63 million kWh
1940	...	178 million kWh
1950	...	500 million kWh

The figures recorded since 1950 show that this trend is unabated. Industrial and mining activities indicate every likelihood to expand on an ever-increasing scale, and the population of the towns is also on the upward path, with consequent increase in domestic consumption.

The electrification schemes in Morocco may be said to have been carried out in two phases. The creation of the body known as L'Energie Electrique de Maroc in 1924, was the first step to co-ordination of energy production in the country, and in that year a steam power station of 24 MW was installed at Casablanca. This authority commenced the exploitation of hydro-electric power at the Centrale de Sidi-Machou on the Oum-er-Rebia, which was commissioned in 1929 with a capacity of 20·8 MW. A 6 MW diesel station at Oujda was also commenced in that year, and in the following year a diesel station, which eventually reached a capacity of 1 MW, was commenced at Agadir.

Important hydro-electric developments were completed in the years 1934, 1935 and 1936. These comprised the small station at Fès-Aval on the Oued Bour Kerareb, with two units totalling 2·2 MW; the El-Kanséra station on the Oued Beth, where two units, with a total capacity of 14·4 MW, were commissioned in 1935; and the Kasba-Zidania station on the Oum-er-Rebia, where in 1936 units with a total capacity of 8 MW were installed. Two years later the total hydro-electric capacity in Morocco was brought up to

a figure of 56 MW by the commissioning of the Lalla-Takerkoust station on the Oued N'Fis, whose two units totalled 10 MW. A number of small diesel and hydro-electric stations were also completed during this first stage, giving a total capacity of 88 MW of thermal and hydro-electric plant, capable in all of producing 230 million units a year to meet a demand which, at that time, was about 150 million units a year.

In 1938 the second phase of intensive development was planned. A new programme of plant installation was put in hand which included, in addition to new hydro-electric and thermal installations, a 150 kV grid network. Unfortunately, wartime difficulties prevented the implementation of these schemes, and it was not until 1942 that the first of the installations planned under this second phase could be put into commission. This was the steam station of Oudja of 24·5 MW, while in 1947 a diesel station at Petitjean, with a capacity of 7·6 MW, formed the next stage in this plan.

Two large hydro-electric installations were installed in 1949 and 1950 respectively at Im-Fout and Daourat. That at Im-Fout has two units, giving a total output of 31·2 MW, while at Daourat the two units installed combine to give a total rating of 17 MW. These two stations together give 205 million kWh a year in normal times, and actually represent an output one and a half times as great as that of all the previous hydro-electric installations in Morocco.

Further installations, designed in accordance with the plans formulated for this second phase of development, are now in the course of construction. These include a large steam station at Roches-Noires, of 120 MW capacity, utilising anthracite from the Djérada Mines, but equipped for the possibility of employing fuel oil in time of emergency.

A very considerable hydro-electric development is under construction at Oued El-Abid. This development comprises two hydro-electric power plants, one at Bin-El-Ouidane and the other at Afourer. The Bin-El-Ouidane plant has three units of 40 MW each, while that at Afourer has two 46 MW units.

The Bin-El-Ouidane plant is scheduled to produce 150 million kWh per annum. The water flow is 160 cu. m. per sec., and the head varies between 61 and 105 m. This station is situated immediately at the foot of the dam at Bin-El-Ouidane, and the water is drawn from the reservoir fed by the Oued El-Abid and the Oued Ahamsal. The total volume of stored water is 1,500 million cu. m., and the superficial area of the lake 3,760 sq. m. From this station the water flows to a smaller reservoir, formed by a dam at Ait Ouarda, and thence through a tunnel under the 1,450 m. high Djebel Tazerkount mountain. It then falls through pressure pipes vertically downwards to the Afourer station, where the head varies between 227 and 235 m., with a water flow of 46 cu. m. per sec. The station is scheduled to give an average annual production of 350 million units.

Fig. 2. The Bin-El-Ouidane dam under construction

The water leaving Afourer passes through a canal which is used for irrigation purposes, and from there it is taken to the Ouem Er Rebia river which flows into the Atlantic Ocean, after passing through other power plants, at a point near Mazagan.

Each of the units installed in the two stations consists of a vertical Francis turbine of 65,000 h.p., driving an 8,500 V alternator at 427 r.p.m. Each station is provided with two 600 kVA 400 V Pelton-driven auxiliary sets. The pressure pipe carrying the water from the Bin-El-Ouidane plant vertically downwards to the Afourer plant comprises two welded pipes covered with helicoidal wire reinforcement. These

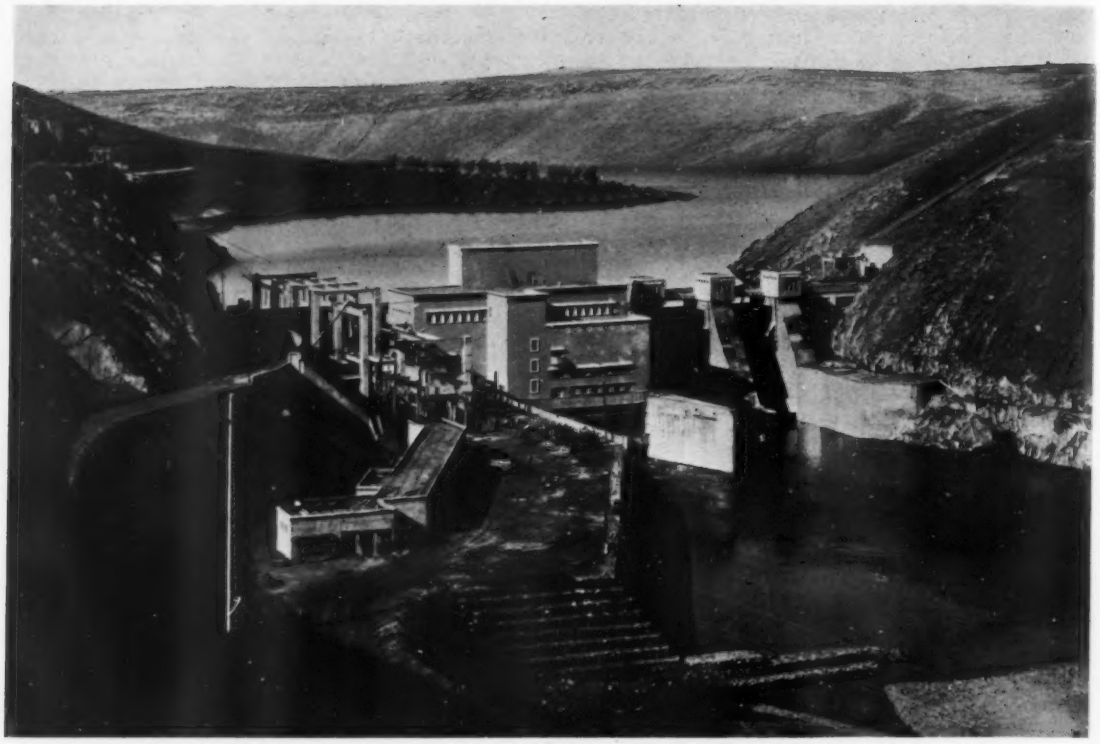


Fig. 3. The dam at Daourat, another station recently commissioned in Morocco

Fig. 4. The commencement of the tunnel leading the water from Bin-El-Ouidane to the second plant at Afourer

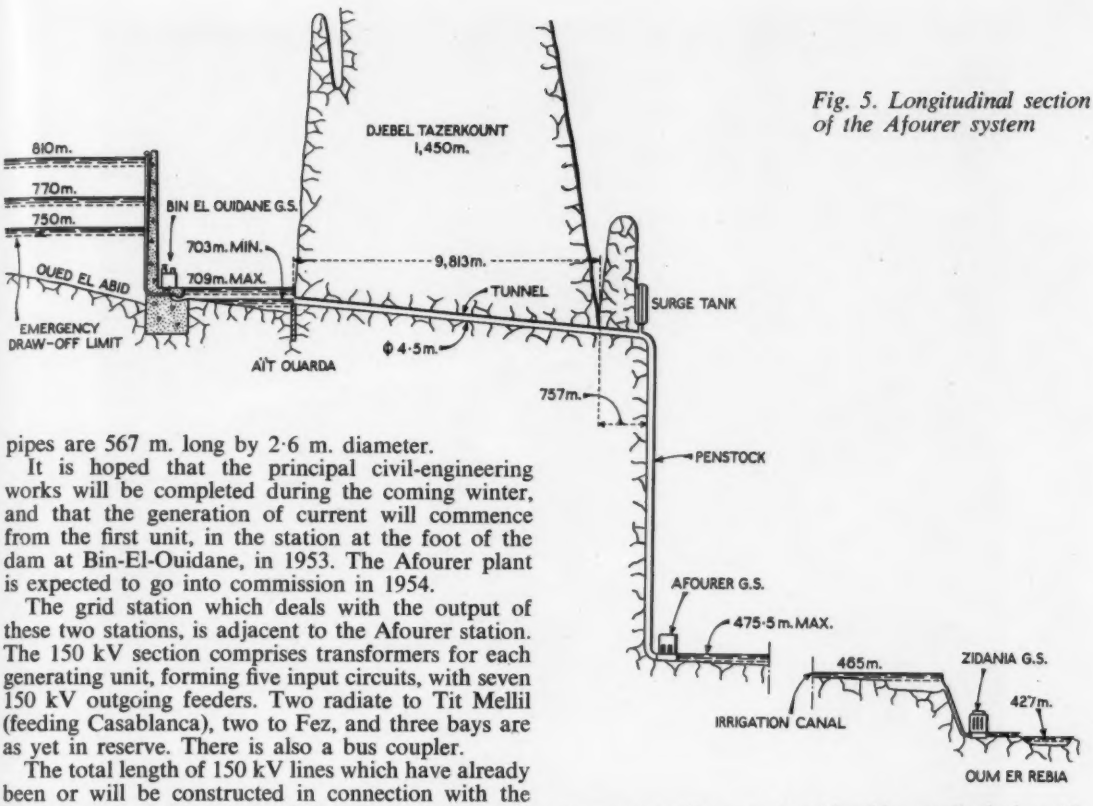


Fig. 5. Longitudinal section of the Afourer system

pipes are 567 m. long by 2·6 m. diameter.

It is hoped that the principal civil-engineering works will be completed during the coming winter, and that the generation of current will commence from the first unit, in the station at the foot of the dam at Bin-El-Ouidane, in 1953. The Afourer plant is expected to go into commission in 1954.

The grid station which deals with the output of these two stations, is adjacent to the Afourer station. The 150 kV section comprises transformers for each generating unit, forming five input circuits, with seven 150 kV outgoing feeders. Two radiate to Tit Mellil (feeding Casablanca), two to Fez, and three bays are as yet in reserve. There is also a bus coupler.

The total length of 150 kV lines which have already been or will be constructed in connection with the transmission of the output of these two stations will reach about 850 km.

In addition to these plans, which may be taken to complete the second phase of electrical development in Morocco, other schemes are under active consideration. It is proposed to increase the thermal power capacity very considerably, particularly with a view to making the best use of the fuel produced from Moroccan mines. It is also proposed to extend hydro-electric developments very considerably, with particular reference to irrigational facilities, which form part of each project. The principal hydro-electric developments which may be expected in future years are a barrage on the Moulouya river at Mechra-Killia, which will stabilise the flow of this river, both for energy production and for irrigation between the French and Spanish zones. A second reservoir, on the Haut-Sebou river at Gantra M'Dez, will play a part in the irrigation of the Saïs plain and also in providing the domestic water supply for the town of Fez. The hydro-electric output obtained from this project has been estimated to be 250 million kWh a year.

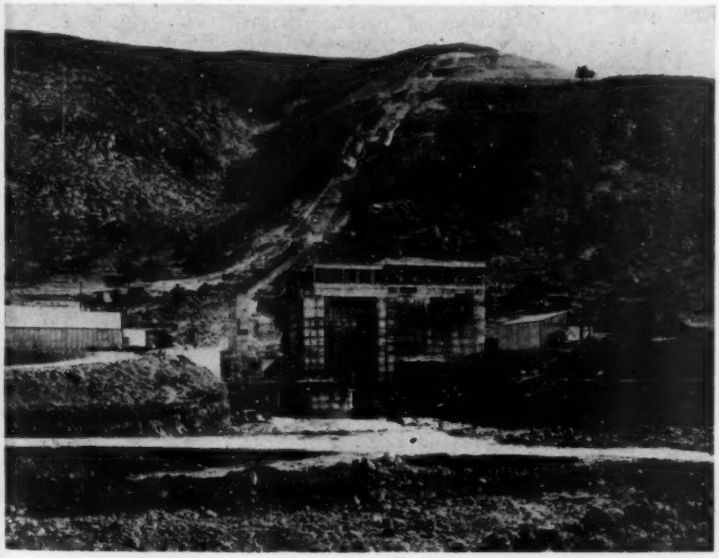


Fig. 6. The Afourer station, showing the plant-house, and in the background construction work on the pressure pipeline

A further series of barrages are also planned on the Oum-er-Rebia which will complete the regulation of this river, and will allow for the production of some hundreds of millions of units each year. The principal installation planned for this part of the future scheme is that at Cheho.

(Continued on page 353)

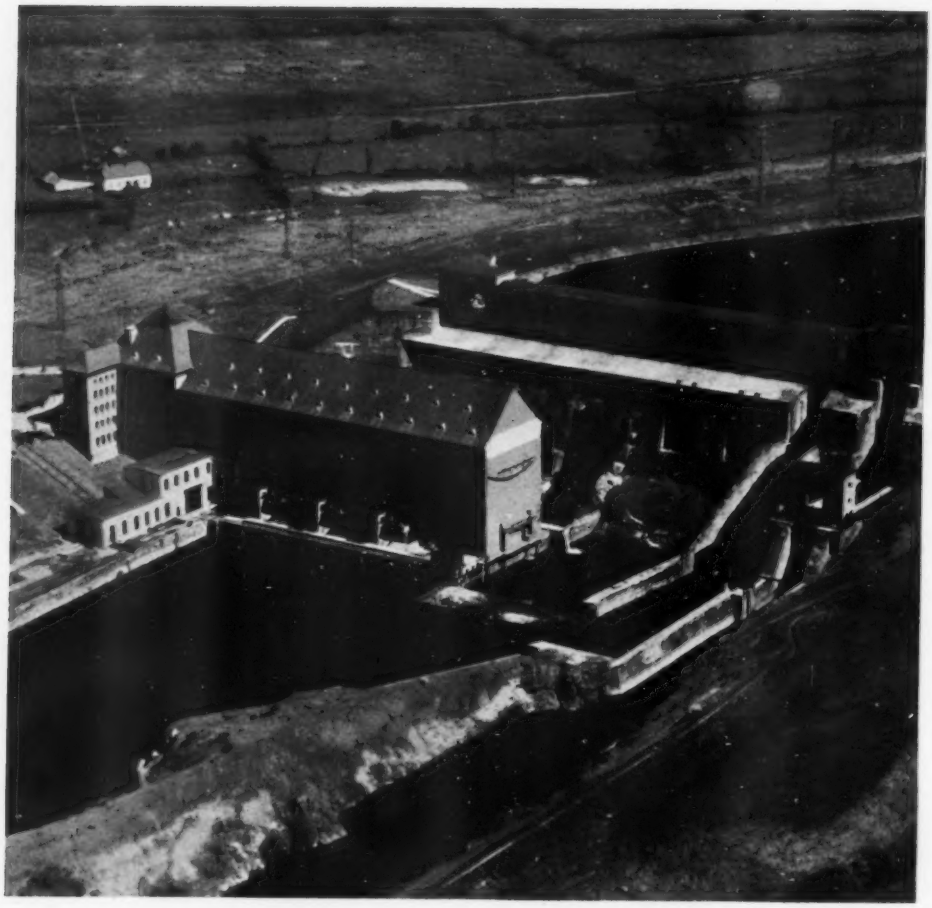


Fig. 1. Aerial view of Ardnacrusha power station

Hydro Plant Maintenance

This article, which is based on a paper read by the author before the Institution of Electrical Engineers in Dublin, describes the work done during a major overhaul of Ardnacrusha hydro-electric generating station, first commissioned in 1929, and the routine developed to afford maximum reliability during a period of acute plant shortage.

By P. BYRNE, B.E., B.Sc.

PART ONE

THE war of 1939-45 created for Ardnacrusha station peculiar maintenance problems, which were difficult of solution. At the time of the outbreak of war in 1939, most of the plant had attained half its estimated life span, and the need for some major works of maintenance had already arisen.

Before 1939, when any major maintenance work was necessary, the services of the manufacturers were available, and, in fact, most of the large jobs were carried out by them. With the war, such assistance was no longer available, and the station personnel were thrown on their own resources. The emergency introduced further difficulties. Standby capacity could not be provided, whereas normally the running plant

on the system always exceeded the load by about 20,000 kW to allow for the loss, through fault, of one of the larger hydro or thermo generating units. Again, the shortage of system plant reduced the time allowable for maintenance to such an extent that a considerable amount of the work had to be done outside normal hours, and as there had been no provision for shift maintenance work, these circumstances provided some difficulties.

Before giving details of the actual work done it will be necessary to give overall particulars of the Shannon hydro-electric development itself.

The river Shannon, in its course of 230 miles to the sea, flows through three lakes, Allen, Ree and Derg, and has a total fall of 300 ft. Ardnacrusha utilises a drop of 100 ft. which occurs in a 12·5 mile stretch of the river between the village of O'Briensbridge and Parteen. A dam with control gates at O'Briensbridge directs the water from the river into an earthen embankment which conveys it over a distance of 7·5 miles to the power station at Ardnacrusha. Thence a 1·5 mile canal, excavated from rock, leads the water back to the river at Parteen. The accompanying Tables I to V give some further details to facilitate identification of items of plant referred to in the text.

The first major work that had to be undertaken during the emergency period was the dismantling and rebuilding of the stator of the third alternator. Though the first work of this nature to be carried out by the unaided resources of the station staff, it had a completely satisfactory result. The core, after rebuilding, gave better temperature readings than either of the other alternators. After this task, the condition of the main machines demanded that each in turn be given a major overhaul, involving complete dismantling of all mechanical parts, checking for results of wear and making good or replacing; dismantling, cleaning and testing of all electrical parts; reassembly of complete machine; finally, application of mechanical and electrical fault simulation tests to ensure that, as far as was practicable, the machine after overhaul was again good for four to seven years' service.

To meet the two emergency necessities, maximum availability and maximum reliability, the following maintenance plan was evolved for the four main generating units:—

Once per month. Each generating unit to receive a mechanical and electrical check-over. Time required—6 to 8 hours.

Once per year. Each generating unit to receive a general overhaul. This includes a detailed inspection for wear in working parts, a thorough cleaning of the exciter, purification of lubricating and servomotor oils, cleaning of the stator from the interior and a general electrical check-over. It does not include general dismantling of parts. Time required —14 days.

Once per 4 to 7 years. Each generating unit to receive a major overhaul. It is completely dismantled and all worn parts made good or renewed. After reassembly, the unit is dried out and then subjected to tests designed to prove, as far as practicable, that the machine is free even from incipient faults. Time required—3 to 4 months.

Space does not permit a detailed description of all the work carried out, but Table VI (overleaf) is a specimen schedule which gives an idea of the attention given to a machine during each type of overhaul.

TABLE I. HYDROMETRIC DATA

Useful catchment area	4020 sq. miles
Average river flow	194 cu.m. per sec.
Maximum river flow	800 cu.m. per sec.
Storage capacity	330 cu. m.
Ratio of storage to annual flow	5·4 %
Average available head	28 m.
Average annual output	300 million kWh

TABLE III. TRANSFORMERS FOR 38 kV TRANSMISSION

Number	1, 2 and 3
Date of commissioning	November, 1929
Rating	30,000 kVA
Ratio	11,000/112,300 V
Tappings	O.L.T.C. boosters (added in 1948)
Method of cooling	Forced oil and air

TABLE IV. TRANSFORMERS FOR 110 kV TRANSMISSION

	No. 1 & No. 2	No. 3	No. 4
Date of commissioning	Nov. 1929	Oct. 1938	Nov. 1949
Rating kVA	8,000	8,000	8,000
Ratio V	11,000/40,300	11,000/40,300	11,000/40,300
Tappings	Separate O.L.T.C.* booster	O.L.T.C.	O.L.T.C.
Method of cooling	Natural oil circulation	Natural oil circulation	Natural oil circulation

*These two boosters were added in 1935

TABLE V. AUXILIARY GENERATING UNITS

	No. 1	No. 2
Date of commissioning	Nov. 1929	Nov. 1936
Speed r.p.m.	1,000	750
Turbine Type	Horizontal Francis	Horizontal Francis
Turbine output h.p.	236	492
At net head m	28·5	26·3
Alternator rating kVA	95	300
Alternator voltage V	400	400
D.C. generator rating kW	—	220
D.C. generator voltage V	—	330

TABLE II. MAIN GENERATING UNITS

	No. 1	No. 2	No. 3	No. 4
Date of commissioning	Nov. 1929	Nov. 1929	Nov. 1929	Feb. 1934
Speed r.p.m	150	150	150	167
Turbine type	Francis	Francis	Francis	Kaplan
Turbine output h.p.	34,000*	30,000	30,000	30,240
Net head m.	28·5*	28·5	28·5	25·15
Alternator rating kVA	30,000	30,000	30,000	25,000
Alternator voltage kV	10·5	10·5	10·5	10·5
System of excitation	Main and pilot	Main and pilot	Main and pilot	Ossana

*These figures refer to the new runner installed in this turbine in 1937.

TABLE VI. ALTERNATOR MAINTENANCE DURING EACH TYPE OF OVERHAUL.

Section of Plant	Monthly Check-over	Annual Overhaul	Major Overhaul
Sliprings	Cleaned and polarity reversed if required.	Cleaned and turned down if required.	Turned down or replaced if required.
Brushgear	Cleaned and worn brushes replaced.	Cleaned, adjusted and worn brushes replaced.	Cleaned, adjusted and worn brushes replaced.
Rotor	Tested with megger.	Cleaned where possible, but not removed. Tested with megger.	Removed and cleaned. Pole bolts tested for permanent set and for tightness. Pole windings re-clamped if protruding mica shows looseness between turns.
Stator	Not attended to.	Cleaned where possible. Tested with megger. Bindings and wedges inspected.	Air passages cleared. Loose bindings made good and end connections varnished. Checked for coil deformation or displacement and for wedge slip. Condition of laminations examined as far as possible. Core bolts tightened if necessary.

Note.—This specimen schedule for an alternator has been compiled from some of the sheets used for recording routine maintenance work on the main generating units—17 such schedules are required for each unit. On completion of the actual work, relevant information is copied into what are termed "Plant Record Cards."

Drying-out of alternator after major overhaul

Drying out is generally carried out by running the alternator at normal speed with its terminals short-circuited, and exciting to such a value as will cause sufficient circulating current to bring the stator to a fairly high temperature, say 65° to 75° C. This temperature is maintained while readings of the resistance of the stator windings to earth are periodically taken. As the drying-out proceeds, the insulation resistance drops continuously until it reaches a minimum value which may be maintained for some hours; it will then show a tendency to rise. After about 24 hours, if the rise has continued or if the resistance has steadied at a value of over 8·5 megohms, excitation may be taken off the machine so that the circulation of current in the winding ceases, and the temperature begins to drop. Temperature and insulation figures are still periodically taken until the former has dropped to a value nearly normal, while the latter has reached a figure approaching infinity in a straight-line curve. The drying out process may then be deemed to have been completed. The operation generally takes one to four days, but unless the circumambient air has been excessively damp, the duration will not exceed 48 hours. Fig. 2 shows curves of heating current, temperature of core, and insulation resistance plotted against time for a typical dry-out.

At Ardnacrusha, the expenditure of water for a dry-out, which is carried out in summer-time when water is scarce, was found to be serious. For a two-

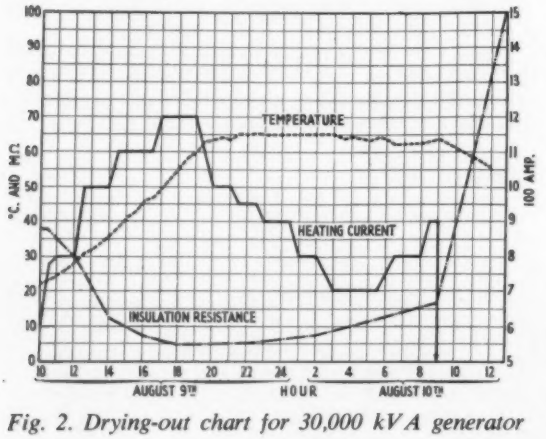


Fig. 2. Drying-out chart for 30,000 kVA generator

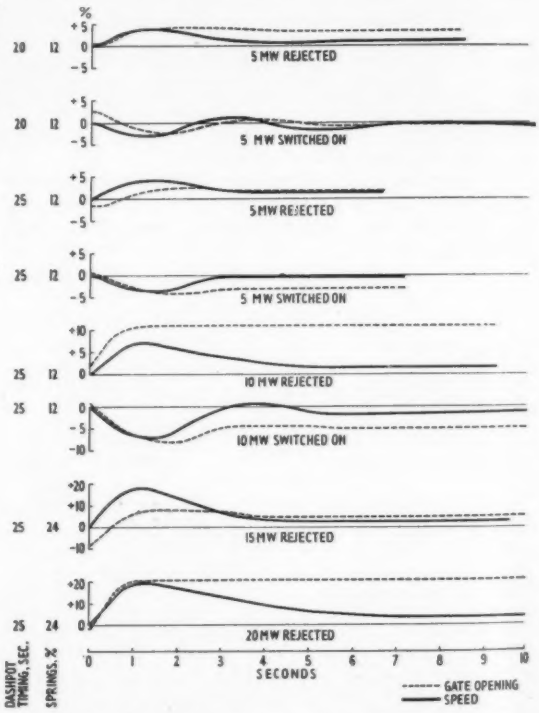


Fig. 3. Tachographic record of governor tests on a 30,000 h.p. Francis turbine

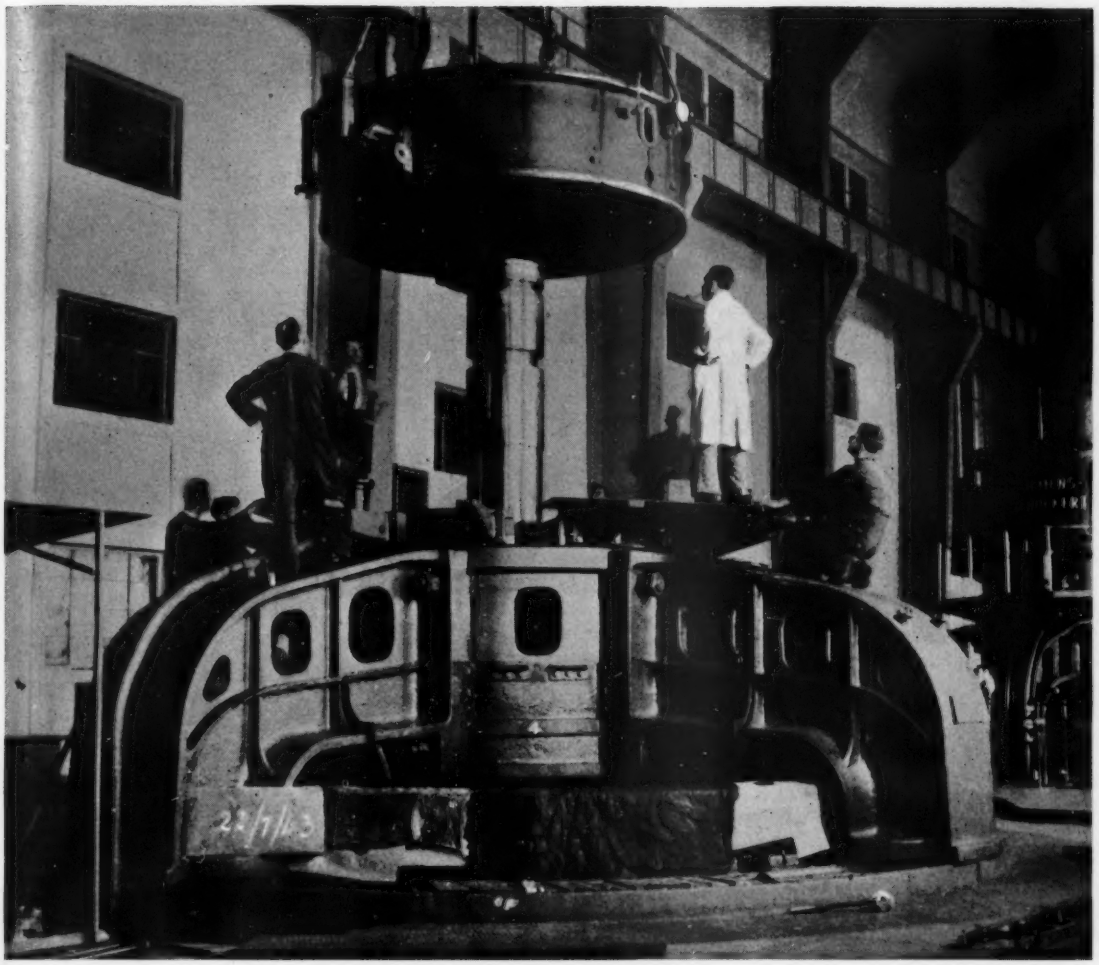


Fig. 4. Thrust bearing being removed from No. 1 machine

day dry-out, one of the Francis machines would consume water equivalent to 200,000 kWh, which, evaluated in terms of production cost by coal (1d. per kWh), amounts to £833. To reduce this cost, a specially designed motor-generator set was purchased. The motor of this set was of the induction type, 230 h.p., and was supplied from the house transformers at 380 V. The generator supplied 1,500 A d.c. at a voltage variable between zero and 110 V to the windings of the stator, the three phases being connected in series. The d.c. voltage required is less than with a.c. because the latter has to deal with reactance and skin effect. The d.c. does not, on the other hand, cause heating of the stator core by eddy current and hysteresis losses, but these effects are not appreciable owing to the small amount of flux involved. The rotor is not, of course, heated by the d.c. method, but it can be dried out separately if found necessary.

Using the motor-generator set for a typical two-day dry-out, 4,000 kWh only would be consumed, i.e., 2 per cent. of the units used by the older method. On each dry-out, therefore, a saving amounting to £816 is effected. The total cost of the motor-generator set was £2,500.

Mechanical tests after major overhaul

An item that must be checked after an overhaul is the clearances between fixed and moving parts at the main bearings and other important points. These clearances are taken after the generating set has been completely assembled and are entered on a drawing arranged to record them in a readily accessible manner. If, after the machine has been put into service, there is an indication that it has fallen out of alignment, clearances will be taken again and checked with those recorded on the drawing. Otherwise, such a comparison will be made before the next major overhaul.

The most important test to be carried out on a generating set is that on the correct behaviour of the governor. The main tests applied are those which subject it to shocks of equal severity to those it may meet in service, the one most commonly applied being that of load rejection. A machine under test is loaded to full or partial load, generally by using a water resistance. The generator circuit-breaker is then tripped and the manner in which the governor deals with the consequent disturbance is registered on a tachograph. Tests in which predetermined loads are

suddenly applied are also carried out. These make greater demands on the governor, because in each case water has to be accelerated to that required to supply the load. In the load-rejection tests, the inertia effect is prevented from affecting the governor action by the complete closing of the gates. In fact, the effect is transferred to the penstocks, where the sudden stoppage of water by the gates initiates a wave of pressure, the effects of which will be disruptive if gate closing is made too fast. A specimen tachographic record of governor tests is shown in Fig. 3.

Electrical tests after major overhaul

At one time, instruments and protective relays were taken down and sent to a central depot for bench testing while the machine was being overhauled. The following were some of the difficulties encountered with this proceduce:—

(a) Delicate instruments and relays, having been tested at the central depot, were occasionally damaged in transport or during re-erection. As they received no further check, the damage sometimes passed unnoticed until a fault of possibly serious proportions developed.

(b) The taking down and re-erection of a large number of instruments and relays left scope for faults in the wiring, either through incorrect rewiring, insufficient care in tightening connections, or in damage by excessive bending of the wire itself.

(c) Gravity-controlled instruments and relays, having been tested in one position, were sometimes erected in another and so functioned incorrectly.

In order to overcome these difficulties, a routine was established of testing with all instruments and relays in position and with wiring, as far as possible, complete as for running. In this, testing is mainly applied to the primary side of instrument transformers, any faults likely to occur in practice being simulated. Protective devices are tested, not only for correct positive action, but also for security against incorrect action by faults which should not affect them.

Prior to the main tests, the following preliminary testing is carried out:—

(a) The insulation to earth of all small wiring is tested to 1,000 V a.c. for one minute.

(b) All voltage transformers, current transformers and shunts, and when time permits, indicating instruments and protective relays, are bench tested over their working range.

Main tests.—The following main tests are then carried out with all relay and instrument circuits intact as for running, except for the temporary connection of substandard instruments such as voltmeters and ammeters:—

Test No: 1.—Alternator on open circuit.

Test No. 2.—One stator terminal connected to earth, inside all current transformers.

Test No. 3.—Single-phase short-circuit between one stator terminal and the star-point, inside all current transformers.

Test No. 4.—Three-phase short-circuit outside busbar current transformers.

Test No. 5.—Three-phase short-circuit inside busbar current transformers.

Test No. 6.—Two-phase short-circuit outside busbar current transformers.

Fig. 5. Upper generator guide bearing of No. 1 machine, showing whitemetal lining scrubbed off

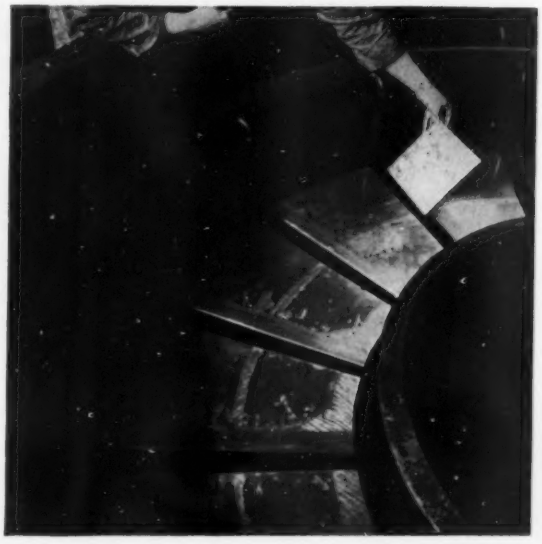


Fig. 6. Thrust pads, showing whitemetal scraped to induce proper wedging action of the oil

Other tests.—The kilowatt and power-factor instruments and the energy meters may be checked against test instruments after the alternator is commissioned. The overspeed relay is removed from the machine and checked by driving with the workshop lathe through a chain of gears.

The fire-extinguishing CO_2 cylinders are checked for gas content by weighing. This is not necessary in the case of No. 4 machine as all the cylinders are normally supported on the pan of a weighing scales, so that a constant check on the gas content may be made.

Time relays are checked with a sekundenmesser. The protective circuits are finally checked for co-ordina-

tion between the various relays. The protection panels of all four machines provide facilities for repeating this check during frequent intervals. It is in fact repeated once per month. Actuating current or voltage is injected by pushbutton control from the voltage transformer into the main relays, in order to check correct sequence of action of auxiliary relays.

Remote thermometers and thermostats are checked by inserting each element in a heated oil bath.

Hydraulic instability

"Instability" in hydro-electric terminology may be defined as a tendency on the part of certain quantities such as voltage, current, speed, etc., to stray outside their prescribed orbits. This vagrant tendency is sometimes unsuspected until the escape has been effected. There are many forms of electrical instability, *e.g.*, an alternator loaded with excessive leading MVA breaks its synchronising tie; one loaded with excessive inductive load and having poor voltage regulation finds its voltage falling away; over-long transmission lines causes the voltage to soar; poorly designed exciters cause voltage fluctuations. We had encountered mechanical instability, chiefly in governors, owing to lack of sufficient characteristic droop, but also, as described later, because of incorrectly machined parts. Hydraulic instability, however, was something new.

On one occasion, the two house turbines, which are supplied by the same penstock, suddenly slowed in speed and refused to do the load demanded, although the gates had been fully opened by the governors. The gauges at the turbine entry level showed that the pressure had dropped to half normal and conditions remained thus until the gates were closed by hand. The turbines were taken down and examined and it was found that sizable eels had gained access to the penstock and partially fouled the runners. It appeared that the eels had made their entry while the screen had been lifted for cleaning. To prevent a recurrence, a lighted lamp was dropped down to the penstock entry during cleaning, so that the illumination might prevent ingress of the eels, which move only in the dark. This device was only partly successful.

As it was believed that the eels provided only a triggering effect and that the basic cause lay in the small size of the penstock relative to the water quantities taken by the two turbines, a test was carried out to find if instability would occur when no such effect was present. The turbines were put on load and the demand gradually increased until a critical point was reached beyond which hydraulic conditions became unstable. At this point, the speed drop and consequent gate opening caused by a small increase in load allowed passage of additional water, which should normally have brought the speed to normal, but this result was nullified by the increased friction head lost in the penstock. Consequently, the governor, still actuated by low speed, caused a further gate opening. This cumulative process continued until full gate opening was effected. At this stage two-thirds of the head was used up in driving the water through the penstock and draught tubes, and the wheels—left with one-third of the head—were unable to deliver any appreciable load.

The turbines are 236 h.p. and 492 h.p. and the penstock, which is 600 mm. diameter and 62 m. long, was designed to supply only the smaller turbine. The larger turbine was erected at a later date and was temporarily connected to the existing penstock. It is intended to install a larger penstock when a favourable opportunity offers. The combined load at which instability occurred was approximately 170 kW.

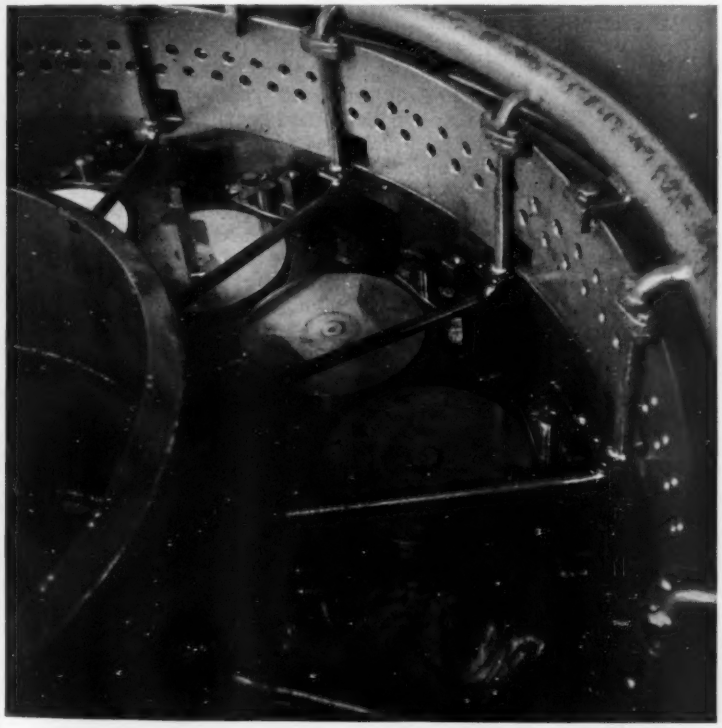


Fig. 7. Wear on the centres of the discs carrying the thrust pads

The turbine runner, composed of bronze, was examined and found to be worn thin and pitted by cavitation, although in 1948 it had been in good condition. The poor state of the impeller would undoubtedly cause an increased water demand and this would account for part of the trouble; a new impeller will be fitted as soon as possible. In the meantime, an opportunity would be found to examine and, if necessary, clean the penstock. For the present, in order to secure the output of the smaller turbine, the governor of the larger turbine will be limited in travel, so that the gate opening will not exceed a value corresponding to 10 kW at 25 m. gross head.

Performance of thrust bearings

From time to time, questions arose regarding the loading and heating of the thrust bearings of the four main generating units. The failure of a similar bearing

TABLE VII. TESTS TO DETERMINE HYDRAULIC THRUSTS ON TURBINES
Gross head approximately 27 m.

Machine Number	1	2	3	4
Type of Runner	Francis	Francis	Francis	Kaplan
	Deflection of thrust bearing in mm. × 10^{-2}			
Gates closed, no water on runner	0	0	0	0
Machine at full speed but carrying no load	19	24·5	30	15·5
Alternator carrying load of 1 mW ...	20	25		32·5
" " " " 2 mW ...	21	27		44
" " " " 3 mW ...	22	27·5	35	45
" " " " 4 mW ...	23	30		45·5
" " " " 5 mW ...	24	31·5	37	46
" " " " 6 mW ...	26	33	38	*46·5*
" " " " 7 mW ...	28	35	39	46
" " " " 8 mW ...	30	36	39·5	46
" " " " 9 mW ...	31	38	41·5	45·5
" " " " 10 mW ...	32	38·5	43·5	45
" " " " 11 mW ...	33	39	44·5	45
" " " " 12 mW ...	34	39·5	45	45
" " " " 13 mW ...	36	41	46	45
" " " " 14 mW ...	37	43	47	44·5
" " " " 15 mW ...	39	43·5	48	44
" " " " 16 mW ...	40	42	48·5	44
" " " " 17 mW ...	42	44		42·5
" " " " 18 mW ...	44	48	50·5	42·5
" " " " 19 mW ...	46	49		42·5
" " " " 20 mW ...	*48*	*52*	*58·5*	39·5
Deflection for weight of moving parts, D ... ... mm × 10^{-2}	81·4	73·6	*	61·0
Weight of moving parts, W metric tons	236	227	227	215
Max. hydraulic thrust, $\frac{W}{D} \times d$ ... ... metric tons	139	160	*	164
Where d = deflection for maximum hydraulic thrust (italicised in schedule above).				

*Tests not complete in the case of No. 3 machine.

in another station focussed attention on the subject. In the three older machines, the temperature of the oil only could be measured, whereas in the case of the later Kaplan unit a thermometer element was embedded in the whitemetal of the bearing; exact comparison as between the different bearings was therefore difficult. Again, a decision had to be made as to how much whitemetal could be scraped away without unduly increasing bearing pressure, in order to give adequate "lead" to provide proper wedging action of the oil. An investigation into the performance of the four thrust bearings was therefore undertaken, including factors such as loading, heat loss and bearing pressure.

As regards the loading, the dead weights of the moving parts supported by the thrusts were known. The additional weights due to hydraulic pressure could be calculated from an empirical formula such as $T = \frac{KD^2H}{2{\cdot}94}$, where T = maximum hydraulic thrust in pounds, K = factor depending on specific speed of runner, D = discharge diameter of runner in inches, and H = head on turbine in feet; but it was thought that the results would not be sufficiently reliable and that measurement would be more accurate. As there was no established procedure that we knew of for doing this, we devised a method which depended on the principle that the deflection of a beam, whether freely or rigidly supported, varies directly as the load applied. In our case, the "beam" was the supporting structure of the thrust bearing, the deflections of which were measured at various outputs of the turbine. For these measurements, a clock gauge reading to 0·01 mm. was used. A check was made by a level of the hydraulic type (two special vessels containing water, fitted with a vernier device for measuring level and connected by a flexible hose) reading to 0·0005 in. Deflection corresponding to the dead weight of the moving parts was also taken and thus the hydraulic thrusts for different turbine outputs were calculable. The results are shown in Table VII and it will be noted that the maximum hydraulic thrust (italicised) occurred at full load for the Francis turbines, but at approximately one-third load for the Kaplan.

The heat loss in each bearing was roughly found by measuring the flow of cooling water and its temperature rise and converting to power units. These measurements were taken after the machine had been on the load corresponding to maximum hydraulic thrust for a period sufficient to allow the temperature to reach a steady value. Examination of these data, though not assumed to be closely accurate, satisfied us that the loadings to which the bearings were being subjected were within their capacity and that the manufacturers' rating, 500-520 tons for each bearing, was conservative.

(To be continued)

The International High-Tension Conference, 1952 (C.I.G.R.E.)—III

The 1952 meeting of the C.I.G.R.E. Conference was held in Paris from May 28 to June 7 and was attended by over 1,000 engineers from all parts of the world. In this, the last of three articles, we review those parts of the proceedings of the Conference of special interest to hydro-electric engineers.

IN this concluding article we first turn from the Cable Section, with which the previous instalment dealt, to overhead-line questions. The problems of towers and tower foundations were dealt with in seven papers, and a number of these were concerned with specialised techniques in regard to small reductions in safety factors, for example, in relation to wind loading and the like, rather than to major points in overhead line support design.

There is obviously still disagreement on a number of questions in this field, but the number of international data on overhead line designs are now so great that every possible condition of ice and wind loading, and operation with one conductor broken, can now be said to be fully documented for the guidance of designers of future overhead-line systems.

The corrosion question in regard to foundations still causes difficulties in certain areas. The use of prestressed concrete was advocated by *M.* P. Lombarde of Electricité et Gaz d'Algerie, who said that in his area no less than 25,000 concrete pole supports have been successfully installed. No trouble with corrosion has appeared, even in places exposed to desert winds, and although earlier attempts at using concrete tower supports were often made impossible by the weight of the structure from the transportation point of view, the prestressed method of construction has done away with this difficulty, and it is now possible to transport complete tower assemblies over distances of up to 150 km.

The tubular structures which have been used in certain Continental countries have been successful, but a number of those who took part in the discussions suggested that the interior of the tubes should also be fully galvanised.

Overhead Lines

The section on the overhead lines themselves again produced seven papers, and one of them was the subject of much discussion. It seems that a number of supply authorities have found difficulties due to the creation of torsion in overhead line cables during unwinding operations. Mr. M. J. Smith, of the British Electricity Authority, stated that British operating engineers have not found any great difficulties arising from this source, but on the other hand, a number of other engineers, including *M.* Poyart of Electricité de France, felt that this unwinding operation might well lead to considerable alterations in the cable structure. It was thought that this question needed further international investigation by the C.I.G.R.E. Committees concerned.

Ice loading on cables was discussed at some length, both in the papers and at the meetings. An interesting point was brought out by *M.* B. Jobin of the Societé Suisse d'Electricité et de Traction. He said that in tests concerned with ice loading in Switzerland, taken at very high altitude, the electrical loading of overhead lines could be used to prevent the occurrence of ice, as long as the cable temperature remains above 0°C. But it was apparently impossible to prevent ice formation by any electrical loading methods if the cable temperature fell below 0°C.

The question of operating existing overhead lines at a voltage higher than that for which they were originally designed was a point which interested many electricity supply engineers in these days when the increase of transmission capacity is a vital matter in so many countries. The possibility of the reduction of the safety factors used in the original design was discussed, and it appeared that in France, at any rate, a number of lines had been successfully operated at voltages somewhat higher than those for which they were originally conceived. Again, it was thought that this was a matter which should be the subject of further research by C.I.G.R.E. Study Committees in the two years before the next Conference.

Maintenance techniques on overhead-line systems have not been a feature of C.I.G.R.E. discussions for some years, but this time an exhaustive paper by Mr. H. R. Schofield, of the British Electricity Authority, dealt fully with every aspect of maintenance work, and gave examples of the many and complicated safety measures employed by his Authority for this work, together with examples of the routine maintenance schedules found necessary on the overhead lines and substation equipment.

To conclude the overhead-line section, the discussions on insulators hinged largely on ageing questions. The toughened-glass insulator is now widely used on high-voltage power lines, and Mr. E. F. Johnston, of Pilkington Brothers Limited of Great Britain, the makers of such equipment, said that his company had supplied insulators to the British Electricity Authority, the North of Scotland Hydro-Electric Board, Northern Ireland, and to power supply authorities in Australia, South Africa, New Zealand, India, and to many European countries.

In the discussion, some French engineers showed that some doubts persisted as to the possibility of assessing the depreciation rates of these insulators. It was thought that hair-line cracks might develop, and that a variation of the stresses in the glass, set up originally by the toughening process, might eventu-

ally occur leading to failure. Mr. Johnston, in his reply, however, was able to prove that the characteristics of the stresses originated by the toughening process of the insulator glass would remain absolutely constant.

He turned the tables, to some extent, on those who criticised these insulators, by stating that the lack of information as to their behaviour was in a great part due to the fact that there had been no failures to record.

The American engineers who took part in the discussion said that according to their experience, the life of a cap and pin porcelain insulator of the cemented type, might be safely estimated at 50 years. The papers in this section revealed experience with line insulators from many countries.

Power Networks

A paper which was rather unfortunately grouped in a "Miscellaneous Section" was that by *M.* P. Henriet, dealing with the evaluation of the structure of major power networks, in relation to the increase in capacity of both thermal and hydro-electric generating units. He showed that as a power network grew, an early decision must be made by the engineers concerned as to whether they proposed it to be a network for interconnection, or one for bulk transport of energy. Problems of sectionalising the network in regard to potential short-circuit power and difficulties of load flow meant that the approach was different in each of these two cases. It might be remarked here, in passing, that this problem was one which the British Electricity Authority had to face in the design of its new supergrid.

Another paper on the same general theme was read by Mr. Walter Dreyer, Vice-President and Chief Engineer of the Pacific Gas and Electric Company of San Francisco. Mr. Dreyer's paper reviewed the historical development of the Pacific Gas and Electric Company's network, and then stated that the principle of integrating a number of small projects into a single large network was one which he commended to other parts of the world where power pools or grid systems did not exist, since it was only in this way that an overall efficient utilisation of both hydro and steam plants could be achieved. Where multi-purpose hydro schemes existed, it was vitally necessary that an integrated power network of large capacity should be available, so that those responsible for the employment of the water could carry out their duties without regard to immediate local hydro-electric generation conditions.

Protection and Relaying

The papers on protection and relaying were difficult to summarise, since each one touched on a particular specific aspect of this problem, and it was not easy to find a theme on which the discussion could enlarge. Single-pole reclosing advocated by Messrs. W. P. Dobson and V. V. Mason of the Hydro-Electric Power Commission of Ontario, was the subject of some discussion, but, in general, it appeared that single-phase reclosing was not widely adopted, and that the three-phase method was generally found more satisfactory. The authors admitted that single-pole reclosing involved a number of complications and difficulties in relaying schemes, but they felt these could be overcome by careful engineering.

The correlation of fault statistics was a subject on which there was some disagreement, and again the Study Committees were asked to endeavour to arrange for fault statistics to be prepared internationally in such a way as to make comparison of operating performance more reliable. When this is done there is little doubt that international statistics, under widely differing conditions, will be very helpful to protection engineers in all parts of the world.

In the system stability section, the burden of discussion was on methods for improving system stability mainly by the use of series capacitators. The growth of the use of this device is shown by the fact that in 1950, only one single installation existed anywhere in the world, at Alfta on the 220 kV Swedish network, while in 1951, a second installation, also at 220 kV, was installed in the United States; now U.S.

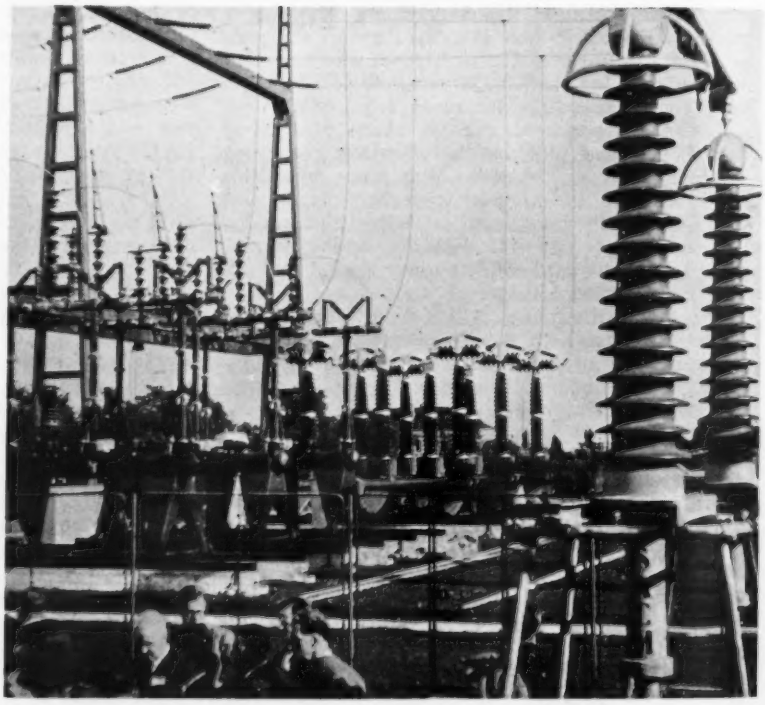


Fig. 1. General view of the Fontenay testing station of Electricité de France with (left) two types of Brown-Boveri airblast circuit breaker and (right) oil filled pipeline-type cable for 220 kV under test, manufactured by SACM (France)

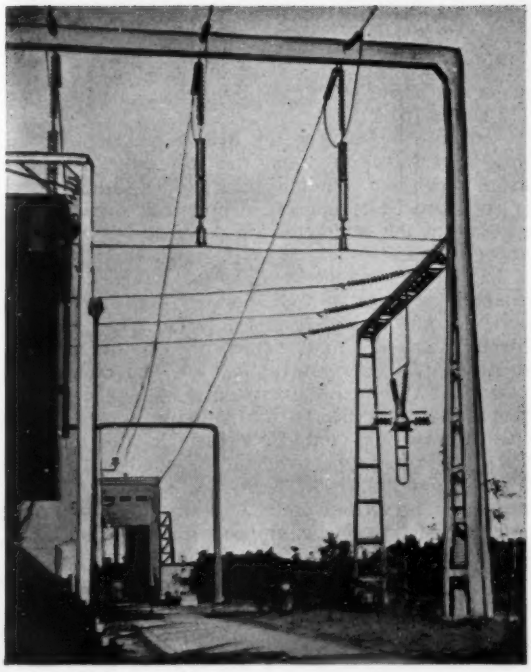


Fig. 2. An example of the light experimental type of circuit breaker seen at the Fontenay testing station. This design for 150 kV is seen suspended from the station steelwork, and is by Merlin and Gerin

engineers and also those concerned with a number of European networks, including the Russians, are planning to install series capacitors to improve transmission line capacity and stability.

The discussion hinged on the location of series capacitors, and on the economic and technical conditions in which they were justified. A number of American engineers suggested that capacitors should be situated either at the ends of transmission lines or at switching stations near the centre of the line, but Mr. Rathsman, Chief Engineer of the Swedish State Power Board, said that physical conditions, for example, in Sweden, dictated the situation of the capacitors, and if there were no intermediate switching stations it was necessary to create a capacitor station in the centre of the overhead-line route.

The protection of the capacitors themselves, and of other apparatus associated with the compensating equipment under overvoltage conditions, was also a matter of discussion, and it is evident that there still remain certain problems to be solved in this direction.

High-speed reclosing, as another method of improving system stability, was used widely in France, and it was hoped to have forty transmission lines equipped with this arrangement before the end of the present year.

The question of the employment of electronic computers for power-system analysis produced a number of papers showing how it was possible to use digital and analogue computers, but it was evident that the time needed for a calculation has yet to be reduced very considerably before these machines can be used regularly by system operators to solve minute to minute problems.

Lightning protection is still one of the most frequent causes of interruption to power supplies, and the papers, although not revealing any new methods of combating lightning outages, went some way towards increasing the amount of information available on lightning problems of all kinds. Among these papers were many that dealt also with switching surges, and some authors suggested that insulation levels adopted for lightning arresters should also be suitable for protection against switching surges. This view was not universally held, particularly as it was generally felt that reliable statistical information on the magnitude and frequency of occurrences of switching surges, is not yet available.

The use of lightning arresters on all voltages down to 6·6 kV in Sweden, in spite of a very low isokeraunic level, was mentioned by Swedish engineers who took part in the discussions, but in Great Britain lightning arresters were not used in spite of the high isokeraunic level in certain parts of the country. It was shown that it was theoretically possible to reduce the impulse test level by the use of lightning arresters and, in fact, that had been done in Sweden and in America.

Once again the 1952 C.I.G.R.E. Conference showed that the use of carrier-current transmission for communication and protective-gear purposes on overhead lines is a growing feature of almost every high-voltage network. The attenuation caused to carrier current by faults was discussed, but it seemed that even a broken conductor down to earth did not prevent operation of the high-frequency transmission, except under the most extreme conditions. The disturbance caused to carrier currents by transient overvoltages, due to faults or to switching were regarded as not being of as much importance nowadays as formerly, owing to

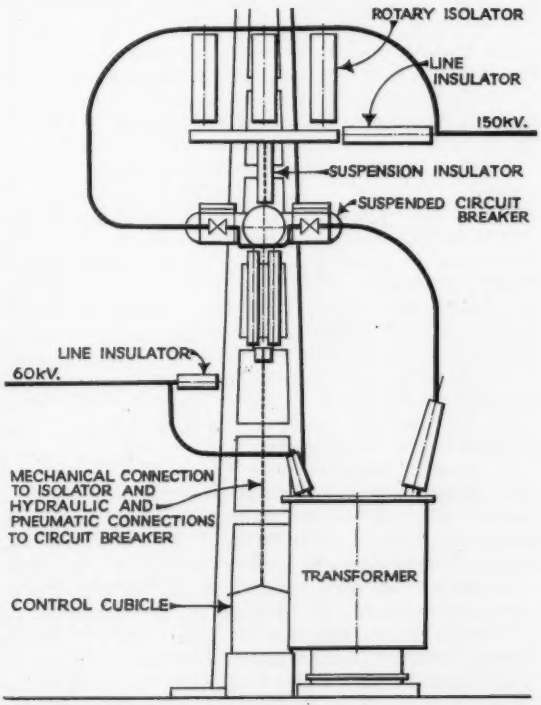


Fig. 3. The Merlin and Gerin 150 kV experimental-type circuit breaker

the great sensitivity of the high-frequency equipment.

There was obviously a difference in practice in a number of countries in this field, as a British engineer mentioned that in Great Britain the high-frequency transmission only takes places at the time of a fault or when a communication purpose is required, whereas in many other countries the H.F. carrier is on the line all the time and is modulated to give the desired information or impulse.

Mr. C. W. Marshall, the Divisional Controller for South-West Scotland of the British Electricity Authority, was Chairman of the session on telephone and radio interference caused by power lines, and in his special report he said that it seemed apparent nowadays that interference due to high-voltage lines did not seem troublesome, even when television receivers were situated in the immediate neighbourhood of the lines. The statement made in the 1950 C.I.G.R.E. Conference and again repeated by American engineers, that radio interference might well be the limiting factor in the adoption of voltages higher than about 300 kV, was not confirmed by the experience of engineers from any other country.

Extra-high Voltages

Perhaps the most interesting aspect of C.I.G.R.E. to hydro-electric engineers was that concerned with the use of voltages higher than 220 kV. The need to reach out towards remote hydro-electric projects was sharply brought into focus by the Swedish papers describing the world's first 380 kV system, made alive on March 31 this year, and inaugurated by King Gustav of Sweden on June 15. This 600 mile transmission scheme, coupling the 300 MW station at Harsprånget in the north to the centre of Sweden, is, in many ways, typical of the sort of transmission problem with which engineers will be faced in many parts of the world in the years to come, in spite of the possibility of atomic energy entering into the power-supply pattern. It has never yet been suggested that the harnessing of water power should be slowed up in view of the possible use of nuclear fission.

From the papers and discussions three main points emerged. The first is that the 400 kV voltage level has now been proved to be perfectly practicable for power transmission. The Swedish scheme (described previously in these columns) involves transformers, cables, switchgear, and protective gear, as well as overhead lines operating at this voltage over the world's longest distance. The satisfactory operation of the line up to date proves that no insuperable technical difficulties are likely to prevent similar lines, designed with special reference to local conditions, such for example as atmospheric pollution, being constructed in other parts of the world.

It must be admitted that the Swedish papers on this subject, with their proud record of achievement in this field, made some of the other papers appear somewhat academic. The British 275 kV Grid scheme, designed to be superimposed on the 132 kV network, was planned to take account of the thermal power generation which will have to be the main source of British energy supplies for many years to come. Two extremely detailed papers from Britain showed that future power stations would be sited at the coalfields, since the transport of energy by electrical means was cheaper than by carrying coal by rail or sea, above a very short transmission distance. The voltage level of 275/300 kV had been adopted in deference to the International Electro-Technical Commission recommendations for voltage levels, although initial plans had been for a simple doubling of voltage from 132 kV to 264 kV.

A tribute was paid to the British engineers for the long-term forecasting and the exhaustive planning detail which had gone into their 275 kV Grid scheme. It may also be of interest to note that a number of sections of this supergrid are designed for operation at the next I.E.C. voltage level, which is 380/400 kV.

The French engineers also stated that they were planning sections of their network for operation at 400 kV, and an interesting Russian paper detailed the plans made in that country for two major transmission links operating at 400 kV and coupling in two 1,700 MW power plants on the Volga, at Kuibeshef and Stalingrad, to the Moscow area. Each of these links would comprise two single-circuit 400 kV lines on Portal type towers, the length of the link being about 900 km. in each case. About 1,000 MW per single-circuit line could be transmitted, and three intermediate stations, equipped with series capacitors, were being employed on each link. Shunt reactors were also provided. Bundle conductors, spaced 400 mm. apart, with a useful cross section of 1,500 mm. per phase, were to be used. Ultra-rapid excitation of the hydro-electric generators was to be employed to improve system stability, and a 75 MVA synchronous condenser was also part of the Russian scheme.

The controversial element in this discussion came from a paper by three American engineers, Messrs. P. Sporn, President, H. P. St. Clair, System Planning Engineer, and E. L. Peterson, Transmission Engineer of the American Gas and Electric Service Corporation. They stated that a figure of 330 kV had been chosen as the next high voltage step in American transmission line planning. They justified this by an intensive survey of cost figures for single and double-circuit lines operating at various voltages over various distances, and they stated that their choice was influenced by Corona-loss considerations, radio interference, sleet melting, hoseline maintenance and general economics.

The discussion, however, showed that none of these reasons appeared to warrant the choice of a non-standard voltage which might well, in the long run, hinder international trading in high-voltage equipment, and in the exchange of operating knowledge. The American power pools already supply 75 per cent. of the electricity consumers in the United States, and some American engineers, who took part in the discussion, said that they felt that most of the energy generated in new plants was likely to be used in the immediate vicinity of the plant itself, and thus only a portion of the energy supplied by the new stations would have to be transmitted.

It was still, however, difficult to assess any real advantage in the 330 kV level as opposed to the 300 or 400 kV levels apparently being adopted in every other country where high-voltage long-distance transmission became necessary. Mr. Adams, of the Federal Power Commission, said that there was a real need in the United States for integrated power pools, and he thought that America might well be on the threshold of a new era of high-voltage development going up to voltages beyond 330 kV. He thought that plans for this should be made now.

There were, however, warnings from one or two of the most senior engineers present, including *M. Pierre* Ailleret of Electricité de France, that standardisation must be the servant and not the master. He agreed that, in general, the choice of a new voltage for an expanding power network should be no less than doube the existing voltage, *M.* Cahen, also of Electricité de France, said that it seemed to him that the 380/400 kV level would be unanimously adopted in Europe.

The Fontenay Testing Station

Delegates to the Conference this year had the opportunity of seeing the progress made at the extraordinarily complete testing station of Electricité de France, at Fontenay, a suburb of Paris. Although from time to time in Sweden, Great Britain and America network tests have been taken on circuit breakers and other equipment, Fontenay, as far as is known, is the world's only completely equipped network testing station in which 220 kV apparatus can be tested directly, with short-circuit powers up to 3,900 MVA

The whole layout of the station has been carried out on an extraordinarily pleasing and dignified architectural and physical plan, and delegates from all parts of the world were unanimous in their admiration of the very complete facilities provided for the testing engineers. On view were seen a number of the minimum-oil and airblast circuit breakers mentioned earlier in these reports, designed with a view to lightness and cheapness, while conventional circuit breakers from Italy, Switzerland, France and the United States were also under test. All these were for operation at 220 kV. Cables, again operating at 220 kV, from six different manufacturers and operating on as many different principles, were also noted in the extensive cable-testing section, where for some two years they have been subject to rigorous long-term load cycles and other testing sequences.

The high-voltage testing hall contains a million volt, 2,000 kVA testing transformer, a 3,000 kVA, 68 kW-second surge generator, and a 100 kV, 100 kA 60 kW-second surge generator for lightning arrester tests. In each case, an extraordinarily exhaustive arrangement of oscillographs, with the greatest possible flexibility, was found to be installed in laboratories permanently equipped for every kind of high-voltage test.

The value of the C.I.G.R.E. Conference in the eyes of many lay only partially in the papers and discussion. The informal exchanges of opinion which took place between the 1,300 delegates may well have stimulated electrical engineering progress in the field of high-voltage large-scale generation and transmission to an extent greater than that achieved by any other professional activity during the two-year interval between this increasingly important conference.

The Yalu Plants

Further to our brief note last month about the bombing of the plants on the Yalu River in North Korea, we have received some interesting details from Ferrum (England) Limited about the important contribution their organisation made to the construction of the Fusenko plant.

Owing to the local topography the pipelines formed a major and vital element in the engineering equipment. For Fusenko I two pipelines were ordered in 1927 and 1928, to be 2,757 m. long, 1,625-1,145 mm. in diameter and operating under a head of 755 m., the total weight being 5,550 tons. Two further pipelines were ordered in 1929 for Fusenko II, which is a lower-head station—217 m.—the pipelines being 576 m. long, 2,250-1,880 mm. in diameter and weighing 950 tons, making an aggregate weight for the four pipelines of 6,500 tons.

All these pipelines were supplied by the Ferrum organisation, and we have been interested to hear that in the recent bombing the pipelines have remained intact.

Large Sluice Valves for Spain

Glenfield & Kennedy Limited, Kilmarnock, have recently completed, to the order of Boving & Co. Ltd., London, the first of three large turbine-inlet control valves for the Los Peares hydro-electric station on the River Mino in north-west Spain. These valves, which are of the balanced-disc type, are each 13 ft. in diameter, some 65 tons in weight and when closed under the maximum working head will carry a load of about 1,100 tons on the door. They are operated hydraulically by a servomotor which is supplied with oil from the turbine governing system and are provided with a motor-driven bypass valve. The entire sequence of operation is automatic.

The turbines are of the Francis type, each rated at 72,800 b.h.p. at 214 r.p.m. under a maximum operating head of 93·32 m. with a water quantity of 66 cu. m. per sec. at full load. Because of a large fluctuation in rainfall over the catchment area, the river flow varies considerably between summer and winter and therefore the turbines have been designed to operate, with a reduction in output, at heads down to 67·73 m. at which head the output will be 53,000 h.p. To conserve water the turbines give their highest efficiency at their lowest operating head.

Ferranti American Contract

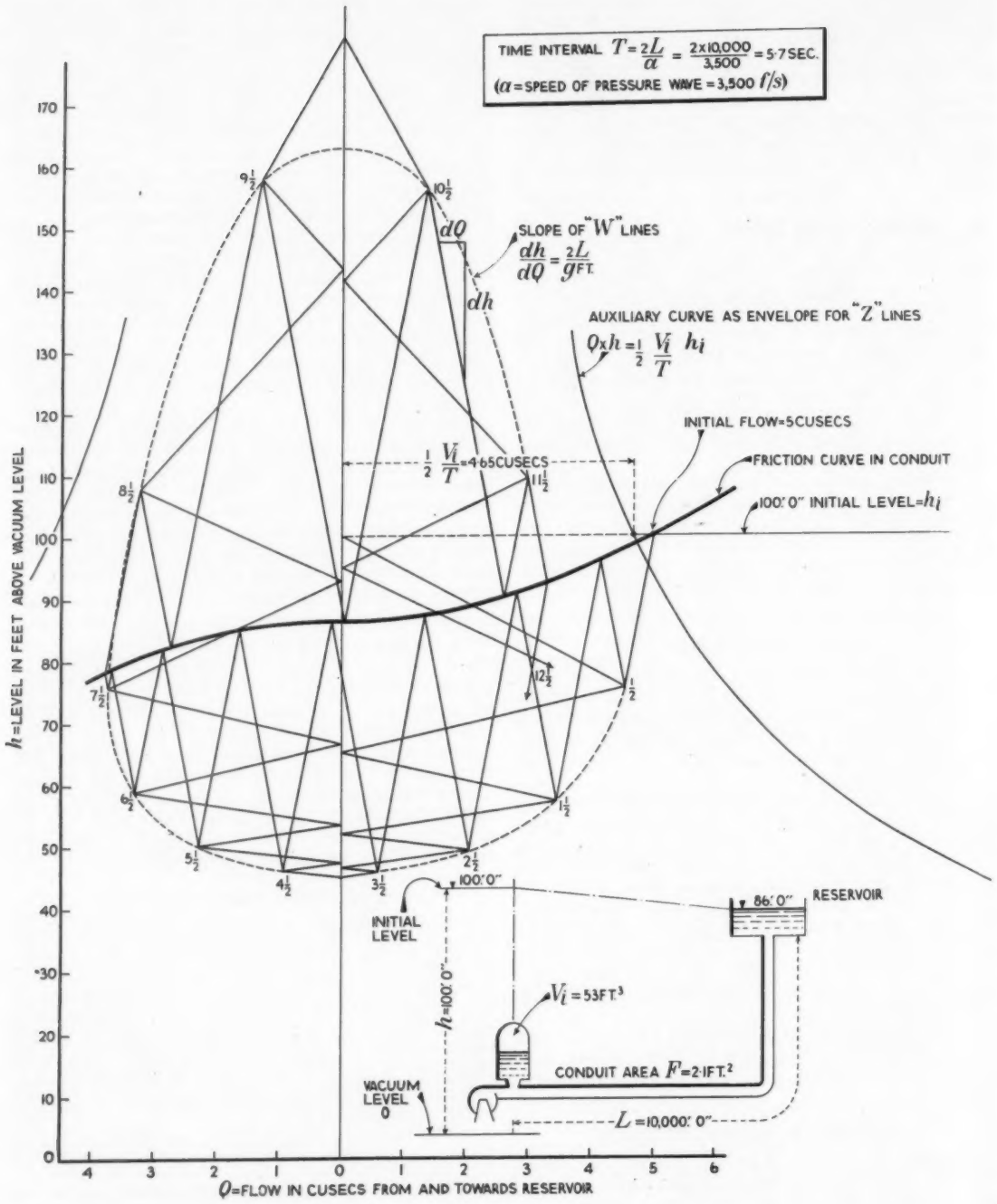
Ferranti Limited, Hollinwood, Lancashire, have been awarded a contract with the U.S. Army Corps of Engineers for the supply and delivery to their Garrison dam project at Riverdale, North Dakota, of nine single-phase 13·2/230 kV 33,333 kVA generator transformers, with water-cooled forced-oil circulation forming three-phase 100,000 kVA banks, each bank connected to the 13·8 kV output of one 80,000 kVA hydro-electric generator with a maximum continuous rating of 97,800 kVA.

From page 341

Finally, a number of regulating installations on the various rivers flowing from the north flank of the Grand Atlas range will eventually permit of the production of considerable amounts of electrical energy.

With the present programme well under way, and with the future plans under active consideration, it is expected that the Moroccan authorities will be able to meet the increasing demands for electrical energy created by the industrial development of the country.

We are indebted to Monsieur Le Directeur Technique au Maroc for the photographs and much of the information needed for the preparation of this article.



LINE DIAGRAMS FOR PROBLEMS OF STORAGE

Fig. 5. Problem of a closed chamber used as a pressure vessel in a pumping installation, treated graphically by a "W" diagram used in conjunction with the "Z" diagram .

Line Diagrams for Problems of Storage

W. E. Blackmore, A.M.I.C.E., A.M.I.W.E., proposes a graphical method to replace laborious step-by-step computations in problems involving storage and acceleration

PART TWO

Closed Chamber

This device, consisting of a pressure vessel, is occasionally used in a pumping installation to guard against the pressure rise which follows a pressure drop caused by a sudden stoppage of the pumps. Under normal conditions the vessel holds a certain volume of air maintained at the delivery-main pressure by a compressor. This air is compressed or expands following the pressure changes in the main, and absorbs or expels a corresponding volume of water. In Fig. 5 a typical case has been treated graphically by "W" diagram used in conjunction with the "Z" diagram. In this case the slope of the "Z" lines is given, for each level, by the tangent at that level to the curve of volume-against-pressure for the air imprisoned in the chamber, doubled to allow for the double rise (outward and return) of the lines during each interval. Assuming the pressure fluctuations of the air to be isothermic, this curve will be a hyperbola $Vh =$ constant $= 2 \times$ initial volume $\times$ initial head (measured from vacuum level as datum) or $2\ V_i h_i$. Now it can be shown that a line drawn through a point at a given level on the vertical axis parallel to a tangent at the same level to the curve $Vh = 2\ V_i h_i$ is itself tangent to an auxiliary curve $Vh = \frac{1}{2} V_i h_i$ or, if flows are plotted as abcissae, $Qh = V_i h_i / 2T$. Two such curves, symmetrical on either side of the vertical axis for the outward and return "Z" lines respectively, are used for the diagram. In Fig. 5, however, only part of the curves has been drawn to save space, and in fact the construction can be done with one curve only, say for the outward lines, the return lines being reflected on the vertical axis at an equal slope. This construction is only valid for complete stoppage of flow. At partial stoppage the "Z" lines will be reflected at points not on the vertical

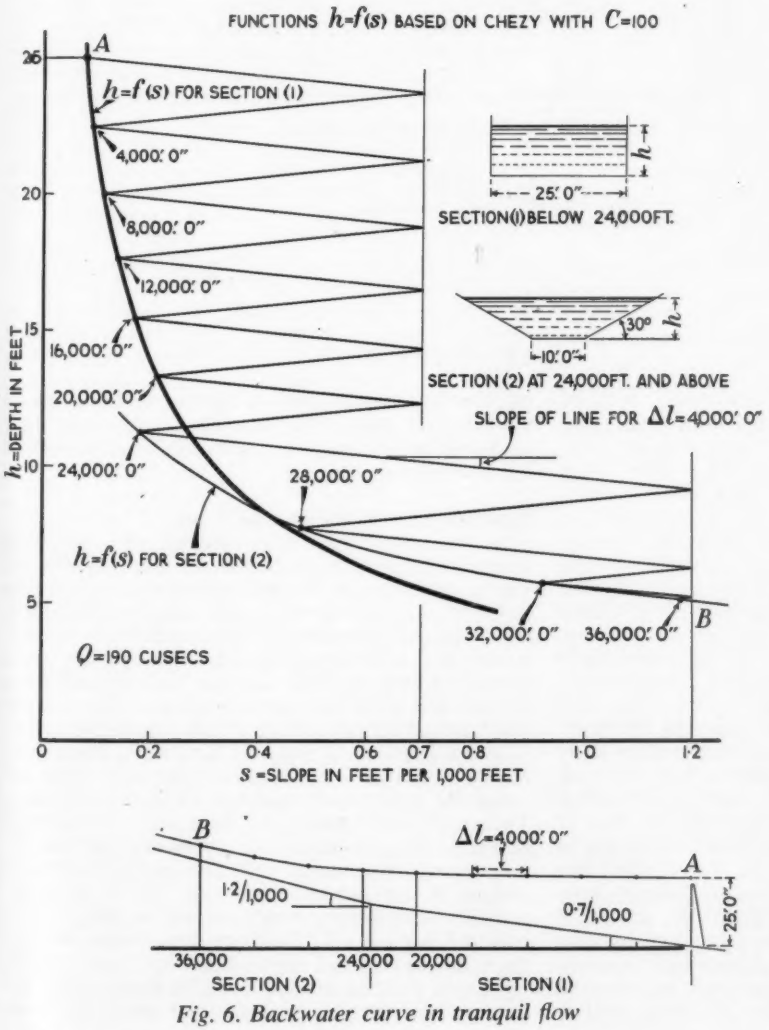


Fig. 6. Backwater curve in tranquil flow

axis. The reflected line must be drawn from this point parallel to a line drawn through a point at the same level on the vertical axis and tangent to the appropriate auxiliary curve. The outward "Z" line is drawn tangent to the other auxiliary curve in the usual way.

Backwater Curves

A method for the grahical determination of backwater curves has already been evolved by Schoklitsch[2]. As it bears some resemblance to the diagrams presented above for storage problems, two applications of his method, with modifications, are given here although the problem is not a transient problem and the question of storage does not arise. The co-ordinates of the diagram are now depth and slope, and each step represents an interval of distance instead of time. In Fig. 6 the case of a backwater curve in tranquil flow has been dealt with. The procedure is as follows: draw the curves of depth h against slope s corresponding to the rate of flow (constant in these problems) and appropriate to the cross-section of the river at each distance interval, all curves being drawn with the same origin. In many cases the cross-section will be approximately the same at a number of points and one curve can be made to cover a number of intervals. In Fig. 6 it is assumed that the river has a constant section (not necessarily constant cross-sectional area of water) from the dam to chainage 24,000 ft. and another section upstream of that point. The datum of depth for these curves should be the gradient line initially adopted as approximating the profile of the river bed. The slope of the "Z" lines will be equal to half the distance interval adopted. The construction starts at point A, being the depth at the dam (chainage 0 ft.) on the curve corresponding to the section at that point. The "Z" lines are then drawn backwards and forwards between the h/s curves and a vertical line with an abcissa on the slope scale corresponding to the datum gradient for the river bed. In the example this datum gradient is assumed to change from 0·7 ft. to 1·2 ft. per 1,000 ft. also at chainage 24,000 ft., and the vertical reflecting line is shifted correspondingly. It will be noted that the "Z" lines are very nearly parallel to the h/s curve between points 32,000 ft. and 36,000 ft.; the "Z" line must not be steeper than the curve and the distance interval must be reduced if necessary to avoid this. Theoretically the "Z" lines will be reflected back and forth indefinitely before reaching point B representing the undisturbed conditions, but in practice the lines may be stopped when sufficiently close to B and the chainage noted as marking the end of the backwater curve.

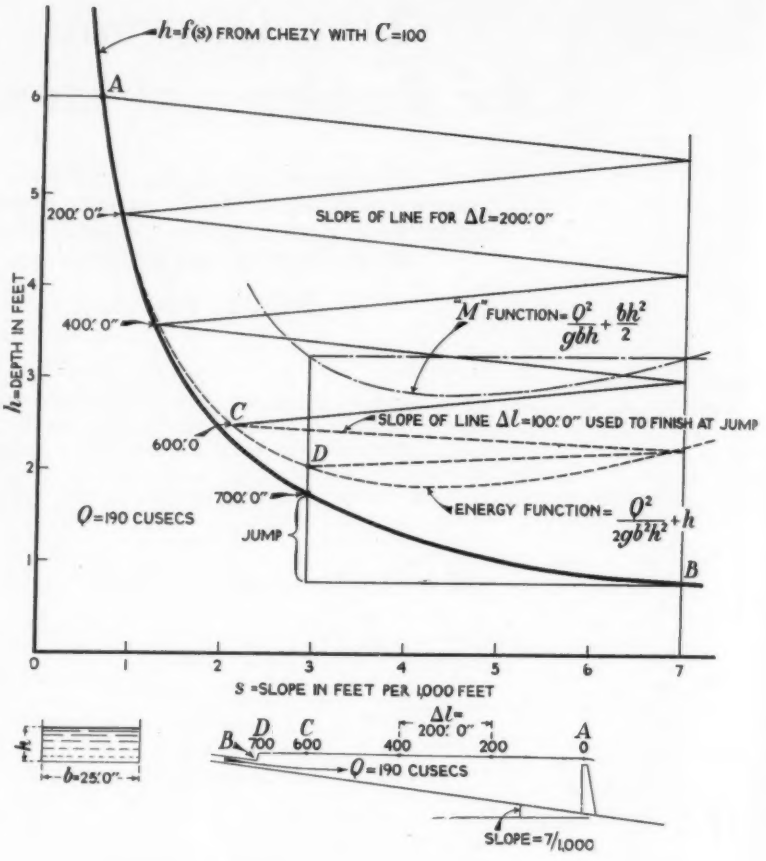


Fig. 7. Backwater curve in shooting flow

Backwater Curve in Shooting Flow

In this case (Fig. 7) it is assumed that the cross-section of the river is constant over the length affected. The h/s curve is drawn and also a curve of energy $(h + v^2/2g)$ against slope; in addition a curve is drawn representing Bakhmeteff's[3] "M" function at any convenient scale and plotted against slope. The flow being a shooting flow, the "M" function has a minimum for a slope less than the datum gradient. The value of this function corresponding to the datum gradient of 7/1000 is found to be repeated for a slope of approximately 3/1000, and a hydraulic jump will occur between the depths corresponding to these two slopes. The depth corresponding to the slope of 3/1000 will be the finishing point for the construction of the "Z" diagram, in this case a well defined finishing point instead of the indeterminate one of the previous example. The construction is similar to the previous example but the "Z" lines are now drawn between the energy curve and the vertical line instead of the h/s curves and the vertical line. The slope of the "Z" lines will be that corresponding to the distance in-

terval except in the last step points from *C* to *D*; in this step the slope of the "Z" line must be adjusted in order to finish exactly on *D* and the slope thus determined gives the length of this last interval and therefore the chainage of *D* where the hydraulic jump will occur.

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[1] Prof. L. Bergeron—"Etudes des coups de bélier dans les conduites; nouvel exposé de la méthode graphique."
[2] Dr. A. Schoklitsch—"Hydraulic Structures."
[3] B. A. Bakhmeteff—"Hydraulics of open channels."

ERRATA

Page 299, Fig. 1, for "Hydrograph of Inflow (level against time)" read "Hydrograph of inflow (flow against time)."

Page 300, Fig. 2, add to the right hand vertical scale the words "Level in feet."

Page 301, Fig. 3, the first surge level obtained by construction should be labelled "$\frac{1}{2}$" instead of "$1\frac{1}{2}$."

Page 303, first column, line 11, delete "(shown dotted)."

Page 354, Fig. 5, the arrow from "Slope of 'W' lines" should be advanced from the dotted to the approximately vertical full line.

Book Reviews

Les Barrages en Terre (Earth Dams), by Ch. Mallet and J. Pacquant. Editions Eyrolles, 61 Boulevard Saint Germain, Paris (V), 340 pp., 197 ff., price 2700 francs.

In this volume the authors present to their coileagues an exposé of the present practice in the design and construction of earth dams. As Prof. K. Terzaghi remarks in the preface he wrote for the book, the brilliant achievements of M. Mallet, a well-known French consulting engineer who was connected with the design and construction of many Algerian dams and bridges, vouch for the high standard of presentation. The publication of this book will hardly fail to have a powerful influence on the future trends of dam construction on French territory. The book must particularly appeal to those who have profited by Prof. Terzaghi's own books and numerous publications on soil mechanics, and it will certainly be read by many specialists outside France.

The first introductory chapter gives a very good summary of the whole problem of earth-dam design, classifying the different types of dams, stressing the points to be studied. Among the information contained in this chapter is a list of 42 destroyed earth dams, giving the reasons for their failure. The second chapter deals with flood discharges, the importance of which is paramount for earth dams. The main paragraphs in this chapter are on the estimate of maximum flood discharge, and types and dimensions of flood discharges. The example are chiefly from North African practice.

Thereafter follow chapters on percolation and piping. The chapter on percolation, containing as it does over a hundred pages, is particularly well presented; (paragraph A deals extensively with the analytical method; paragraph B is on arithmetical integrating, the method of Southwell being just mentioned; C on electrical analogy; D on models; E on graphical methods). The flow-net diagrams, the use of which is so important for all practical purposes, are neither explained nor referred to in this chapter. Chapter IV on the methods for preventing piping is one of the most interesting, dealing with the different types of cores, drains and filters, with many examples from Algerian and Swedish dams. The chapter on stability opens with the usual references to Mohr's criterion of failure and to Rankine's passive and active states (the letters used are those of French treatises). Then follows the exposé of the French method of Caquot and the so-called "Swedish method" of K. E. Patterson. The last chapter, on materials and methods of construction, is chiefly based on American practice (U.S. Bureau of Soil Classification). The examples on the hydraulic compaction method are also based on American practice.

The book makes use of the reports submitted at the Second and Third Congresses on Large Dams (Washington 1936 and Stockholm 1948) and the Second Congress on Soil Mechanics (Rotterdam 1948), of which mention is made in the bibliography.

Comments by Prof. Terzaghi on American experience on large earth dams (pages 333-336) bring to a close this book, which is to be recommended to any engineer dealing with earth dams or interested in soil mechanics.

Electricity Supply in Great Britain. By Sir Henry Self and Elizabeth M. Watson. George Allen & Unwin Limited, 40 Museum Street, London, W.C.1. 1952. 219 pp. Price 20s. net.

This book is the second of a National Board Series describing the development and organisation of Britain's nationalised industries. It traces the growth of the electricity supply industry from the 1880's, through the period of the local undertaking and the conditions of the first world war to the establishment of the Central Electricity Board in 1926. The development of distribution and the pre-nationalisation situation are then discussed, leading to the transfer to national ownership and the administrative structure under nationalisation. Important chapters then follow on labour and education problems, the consumer interest, immediate tasks, finance and economics, and a general review of the status of the industry. Various appendices relating to organisation and statistics conclude the book.

Traité d'Irrigation. By V. Bauzil. Editions Eyrolles, 61 Boulevard St. Germain, Paris V. In two volumes: text, 418 pp. 210 ff.; and "atlas" containing 19 tables and 8 folding plates. Price 5,500 fr.

In this book the author, who is Chief Engineer of Bridges and Highways, makes a comprehensive study of irrigation engineering. After a few introductory chapters on fundamental irrigation requirements and on a review of the relevant hydraulic formulae, he proceeds to a study of canals and irrigation networks, discussing the factors influencing the course of the main canal, its cross-sectional profile, water losses, and types of lining. Dams and civil-engineering works next come in for review, then drainage and the use of subterranean waters. Finally distribution systems are considered, and questions of administration and tariffs.

Tungsten Filament Lamps. The International Electrotechnical Commission, 39 Route de Malagnou, Geneva, has sent us a copy of publication No. 64, "International Specification for Tungsten Filament Lamps for General Service." Price 5 Swiss francs plus postage.

Abstracts from the World Technical Press

Building Falcon Dam—in Two Languages

Straddling both the U.S.A.-Mexico boundary and the Rio Grande River at a sun-baked site near the lower tip of Texas (Fig. 1), Falcon dam is multi-purpose in design and international in character. This compacted rolled earth-filled structure, which will lack just 106 ft. of being 5 miles long (16,160 ft. in Mexico, 10,130 ft. in U.S.A.) is being built for the International Boundary and Water Commission as a joint undertaking of the two countries.

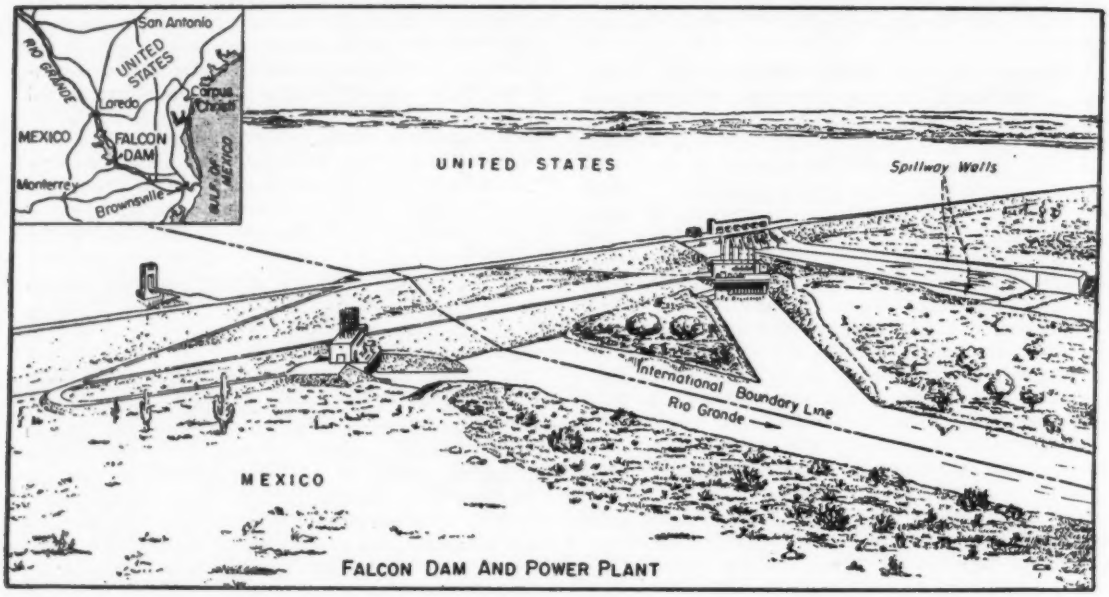


Fig. 1. Perspective sketch and plan of the Falcon dam and power plant on the U.S.A.-Mexico boundary

The height of the dam above stream bed is 150 ft., with a width of 35 ft. at the crown and a maximum width of 1,000 ft. at the base; the spillway, designed for a maximum capacity of 456,000 cusecs and equipped with six 50 × 50 ft. fixed wheel gates, is 350 ft. long at the crest, its chute is 1,300 ft. in length. The reservoir created by this huge structure will have a total capacity of 4,085,000 acre ft., with an area of 78,000 acres at conservation pool level, and 113,000 acres at maximum pool level. The material involved comprises 12,500,000 cu. yd. of earth and rock fill, 420,000 cu. yd. or riprap, 261,000 cu. yd. of concrete, 11,000 tons of reinforcing steel, and 6,500 tons of fabricated steel.

The chief function of the dam will be to conserve the three million acre ft. of water that annually wastes into the Gulf of Mexico.

Work began officially on January 2, 1951, with the establishment of temporary offices at Rio Grande City, Texas, and San Pedro, Mexico. Embankment construction is on schedule; similar to other rolled fill dams, the embankment is made up of a central section of impervious material, including a 150 ft. maximum width cutoff extending into the rock. The upstream face will be protected with a 3 ft. blanket of riprap, and the downstream face with dumped rock; in addition to the controlled spillway built on the U.S. side of the river, each country will have its own outlet works.

The two almost identical power plants, one on each side of the river, will initially house three 10,500 kW generators and ultimately four such units each; the plants, interconnected for energy transfer, will generate together 200 million kWh of primary, and 50 million kWh of secondary energy, equally divided between the two countries. Many overall procedures are simplified by the fact that the U.S.A. and Mexican construction contracts were awarded to one group of contractors, known as Falcon Dam Constructors and Compania Constructora Intercontinental S.A. respectively. For example, all concrete is mixed on the

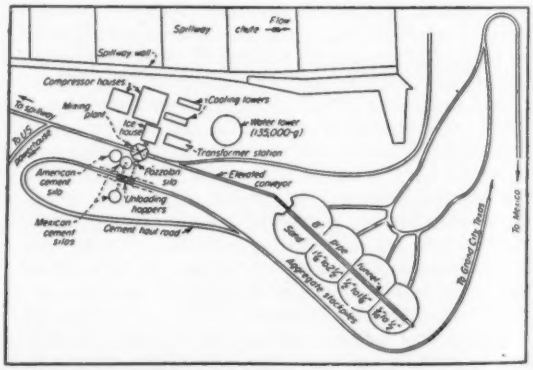


Fig. 2. The central concrete plant located between the U.S. power house and spillway chute

U.S. side while all aggregates are produced near by on the Mexican side.

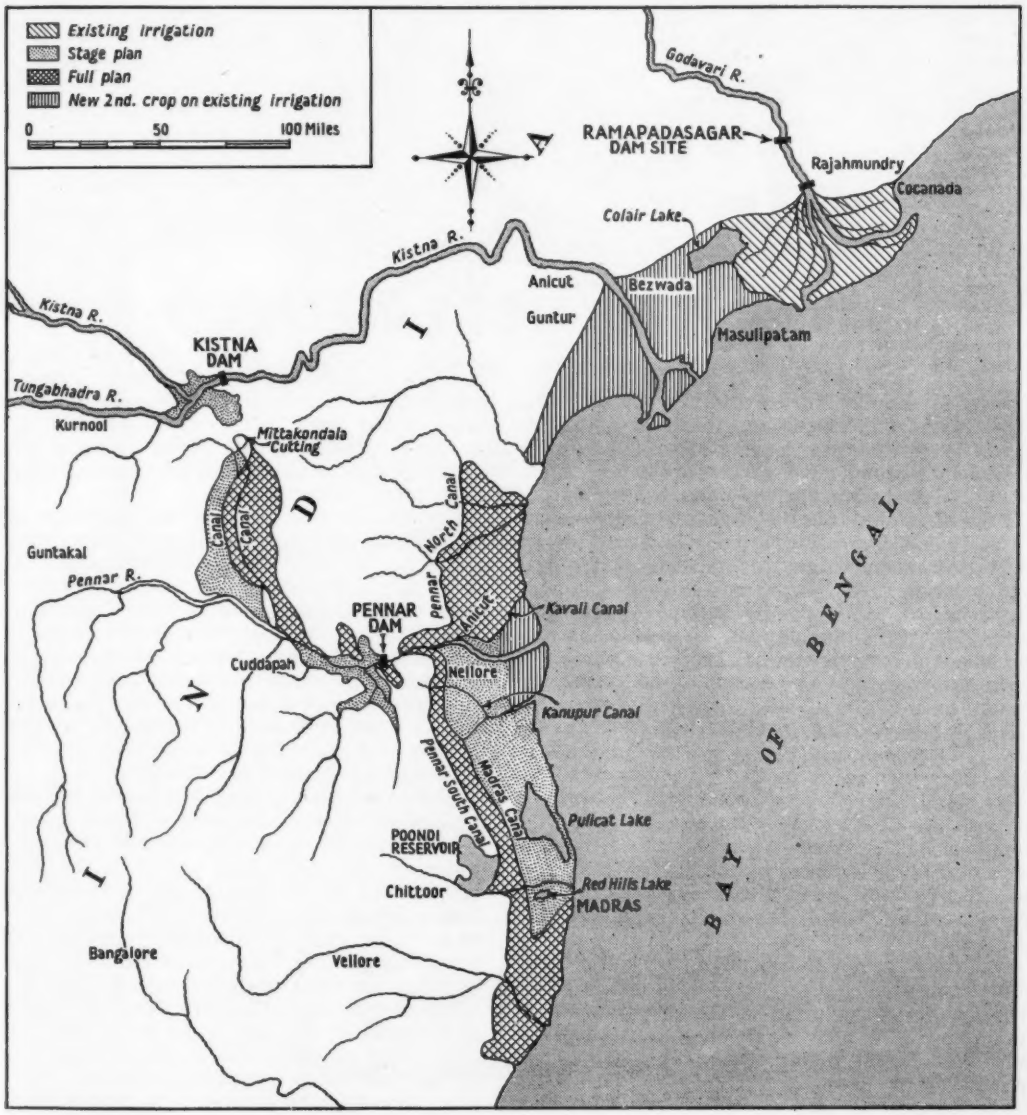
The concrete plant (Fig. 2) is serviced by four storage silos, and a large ice plant ensures a production of 120 tons of ice in 20 hours, as much as 150 lb. of tube ice being required for cooling a 2 cu. yd. batch of concrete to 80°F. Gravel and sand used for aggregates are produced in a 150 ton per hour screening and washing plant which recovers 60 per cent. of the material processed.

Diversion of the river is scheduled to start next November, when stream flow is expected to be not more than 2,000 cusecs, and a temporary cofferdam will close off a 500 ft. gap in the embankment, diverting the river through the 22 ft. diameter penstock and the Mexican power house. The whole dam is to be completed in November 1953.

This article also deals at length with the procedure of co-operation between the U.S.A. and Mexican engineers. In this respect, every detail has been worked out in advance, and the job runs with equal smoothness on both sides of the river; no difficulties have ever arisen out of the fact that all discussions and consultations proceed in English and Spanish. (*Engineering News-Record*, Vol. 148, May 15, 1952, No. 20, p. 62, 4 pp., 6 ff.)

The Kistna-Pennar Project, Madras

The Kistna-Pennar project, as now revised, consists of two dams, one on the Kistna river at Siddeswaram in Kurnool district, and the other on the Pennar river at Someswaram in Nellore district; the Kistna dam is a purely masonry structure, whereas



Map of the Kistna-Pennar project

the Pennar dam consists of a masonry structure fairly similar in design to the Kistna dam, and of an earth structure. The two lakes formed by these dams will have an aggregate capacity of about 555,000 M cu. ft., i.e. about six times the size of the Mettur reservoir, and will be linked up by the Kistna-Pennar canal dug through a cutting called Mittakondala cutting. At the downstream end of this cut, which is about three miles long and 100 ft. deep at the deepest point, the waters diverted from the Kistna will be let into the Kunderu river through one of its tributaries, and will flow for a distance of some 115 miles before they fall into the Pennar river.

The main characteristics of this multi-purpose scheme are as follows:—

I. Storage Works

	Kistna Dam	Pennar Dam
Length of masonry structure	3,300 ft.	2,400 ft.
Length of earth structure	—	1,300 ft.
Height above river bed	130 ft.	160 ft.
Volume of masonry structure	32·4 M cu. ft.	28·0 M cu. ft.
Volume of earth structure	—	162·0 M cu. ft.
Full reservoir level ...	+898·5	−378·0
Capacity	279,000 M cu. ft.	276,276 M cu. ft.
Power installed ...	120,000 kW	120,000 kW

II. Diversion Works

(a) Canal linking up the Kistna and Pennar reservoirs, and following the Kunderu valley on a length of 118 miles; discharge 45,000 to 75,000 cusecs.

(b) Pick-up barrage below Pennar dam, 2,000 ft. long, 25 ft. high; flood discharge 500,000 cusecs.

Owing to the many years required for the completion of the full scheme and the large outlay involved (Rs. 130·3 crores), work is to be split into two stages. In the initial stage, which aims at the irrigation of 21 lakhs acres, the two dams will be built to their full dimensions but only four of the new canals (Kistna-Pennar West, feeding the Gandikota reservoir, Kavali, Kanupur and Madras canals); the final stage comprises the three remaining new canals (Kistna-Pennar East, Pennar North, and Pennar South). These seven new canals, together with existing canals, and the Kistna and Pennar Deltas, will ensure the irrigation of an area of 3·6 M acres; the Pennar South canal, of which the Madras canal is a branch, and the Pennar North canal will take off above a new shuttered barrage to be built downstream of the Pennar dam.

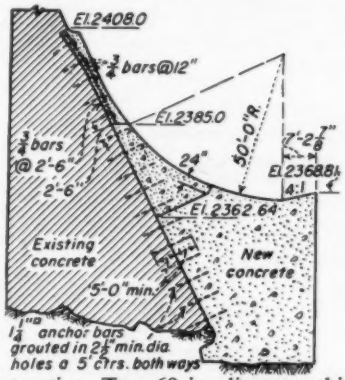
The continuous power generated will be 100,000 kW, and the 250,000 kW installed will ensure the development of seasonal power, the potentialities of firm power being increased by the linking of the grid with thermal units; small blocks of power will also be produced at about half a dozen major drops on the canals.

In addition to power generation, irrigation, flood control, partial navigation and recreational facilities, this extensive scheme, in its initial stage, will provide drinking water for the city of Madras, and it is expected that 27,000 tons of fish will be produced in the reservoirs and canals. (A. R. Venkatachari, Chief Engineer, Irrigation, Madras. *Indian Journal of Power and River Valley Development*, Vol. 1, No. 12, Nov. 1951, p. 17, 4 pp., 6 ff.)

No time to spare in Dam Repair

Black Canyon dam, a 183 ft. high concrete gravity diversion structure on the Payette river, 25 miles north-west of Boise, Idaho, was built originally with a straight overflow spillway, *i.e.* without any apron or concrete stilling basin. Since its completion in 1924 water flow had eroded natural rock away from the spillway toe; the erosion undercut the toe, and some uplift pressure developed. To eliminate the risk of further erosion and undercutting, the U.S. Bureau of Reclamation adopted an emergency repair procedure which involved the placing of a 5,800 cu. yd. concrete apron at the toe of the spillway.

Since Black Canyon is a diversion dam, the first major job was to set up a concrete flume in front of the power house to handle the water during construction. Two 60 in. diameter thin-wall (¼ in. thick) steel pipes spanned the 100 ft. or so between the outlet valves in the dam and the flume. Thus the flume carried water from both the power house and the outlet conduits, the whole system being designed to handle flows which, according to specification, might reach 3,000 cusecs.



New concrete added at toe of spillway to protect it from further erosion and undercutting

The second major construction problem was to complete the work before start of the high spring flow in the Payette river; that meant dewatering the toe of the dam and placing the necessary concrete, all of which had to be done during winter operating conditions. Weather worked in favour of the job in that work was not unduly delayed by storms, but low temperatures required special measures in mixing the concrete. Water was heated to 140°F., and calcium chloride was added to the mix at the rate of 1 per cent. by weight of cement, so as to promote faster setting.

Dewatering began on February 1; concreting started on February 23, and was completed on March 25, literally minutes before high water would have drowned out the work until autumn. Actually water poured over the spillway on March 31. The contractor had just had time to remove the diversion pipes and their cribbing, but water rose so fast that the demolition of the concrete diversion flume by blasting became impossible. Removal of the flume wall is to be completed this autumn during low water.

The last phase of the work consisted in adding a 10 in. extension on each of the drum gates, so as to add storage capacity, and to project flow out from the spillway during overflow conditions. The extensions were made by welding ¾ in. plates to the drum. (*Engineering News-Record*, Vol. 148, No. 22, May 29, 1952, p. 50, 3 pp., 8 ff.)

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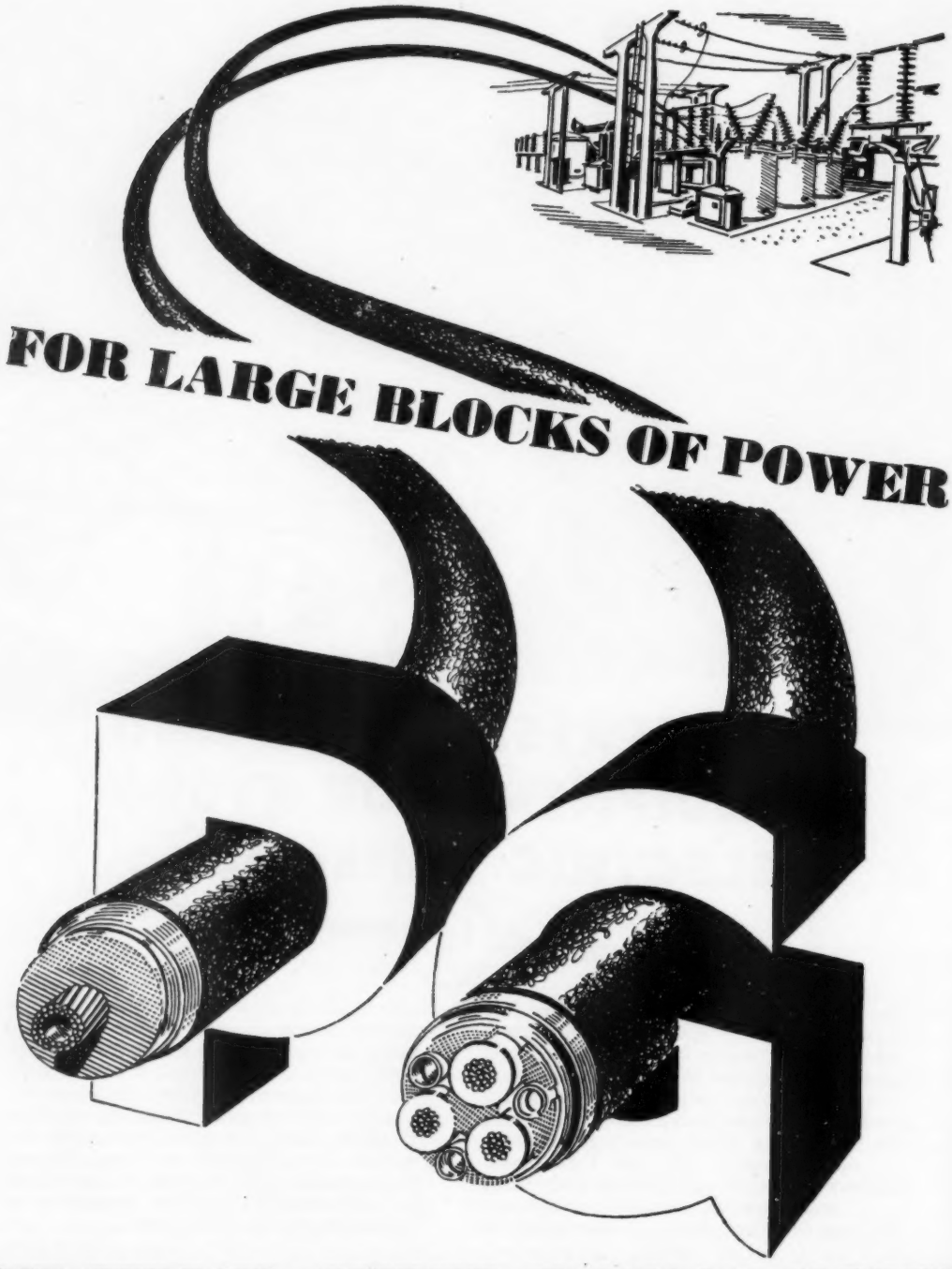

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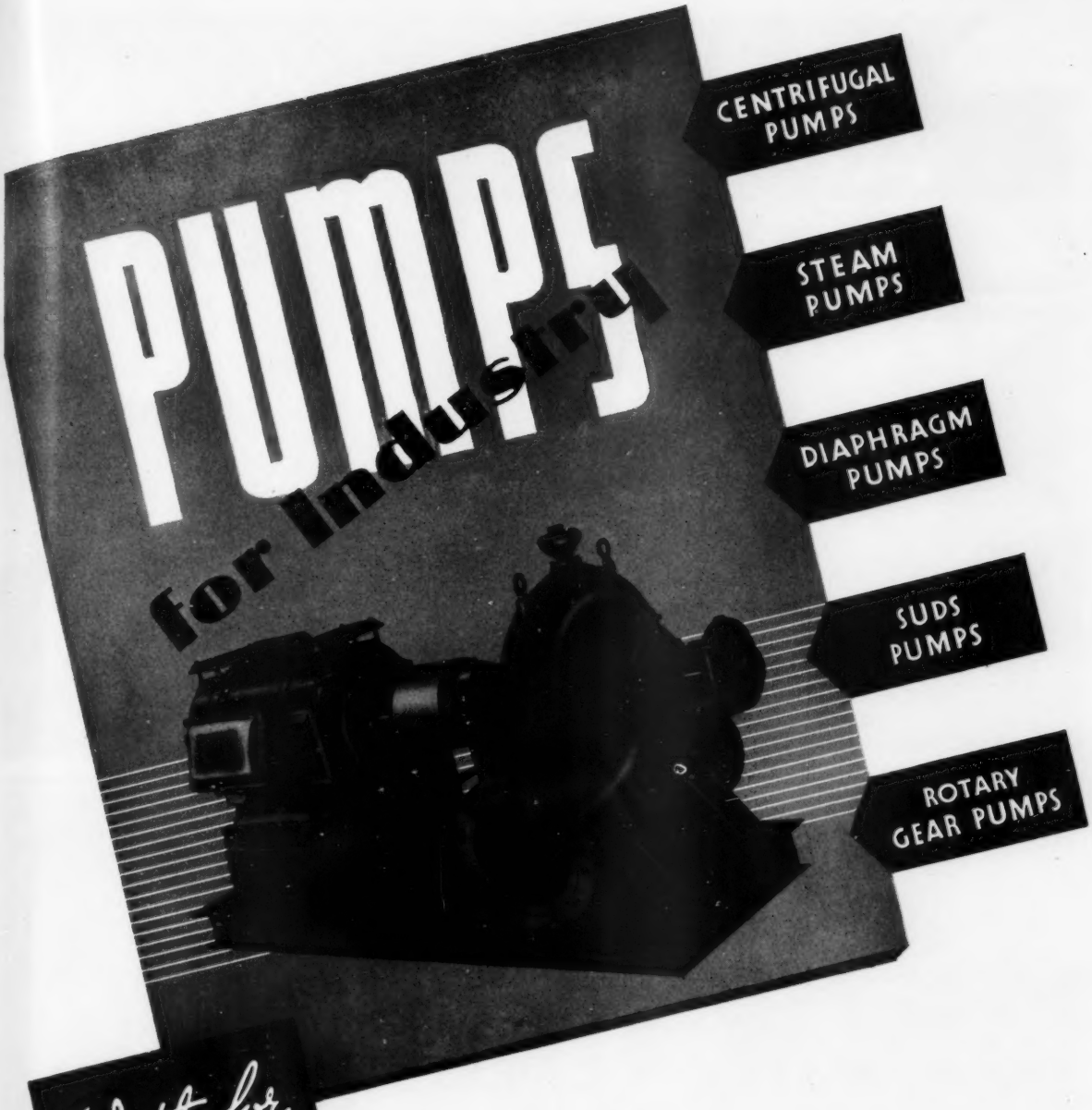

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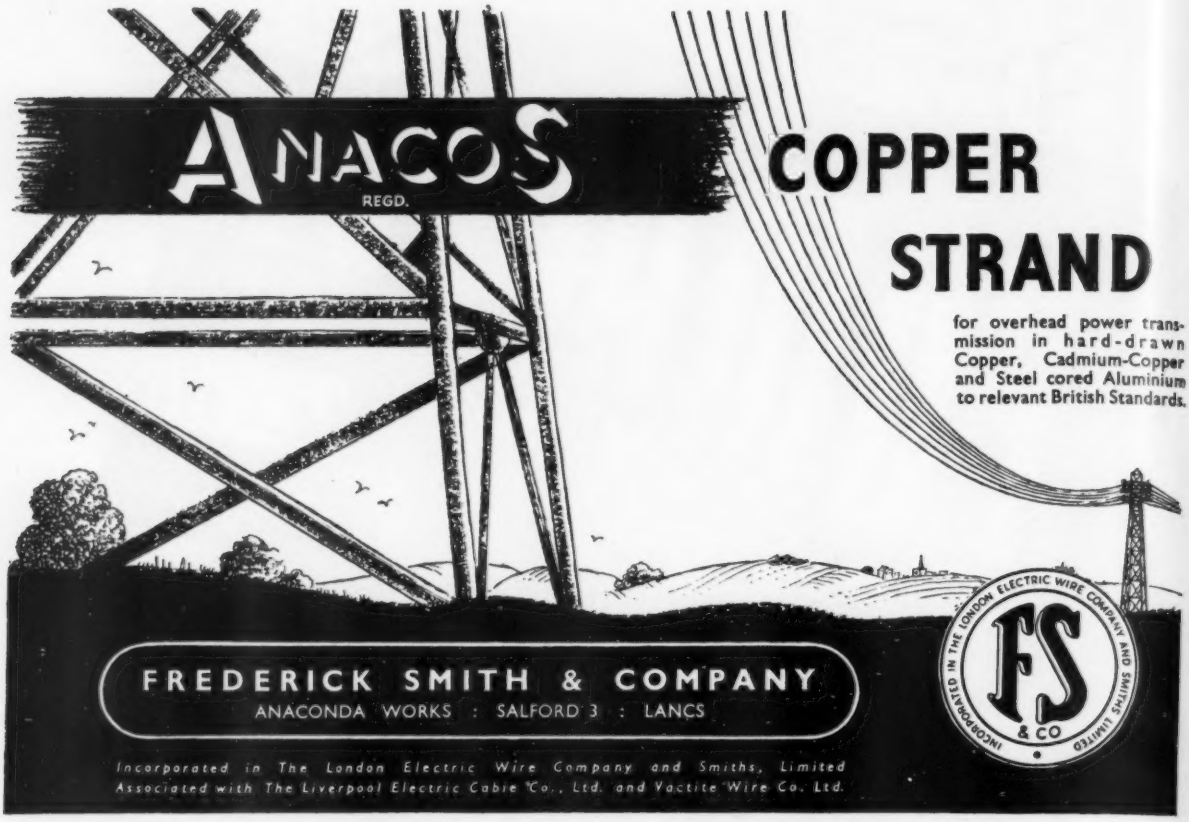
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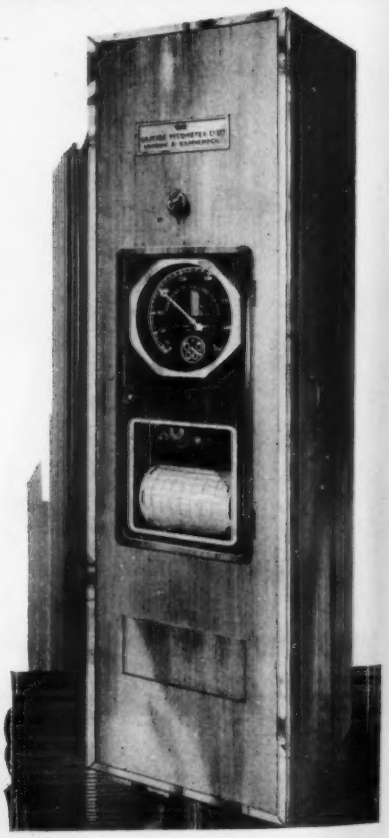

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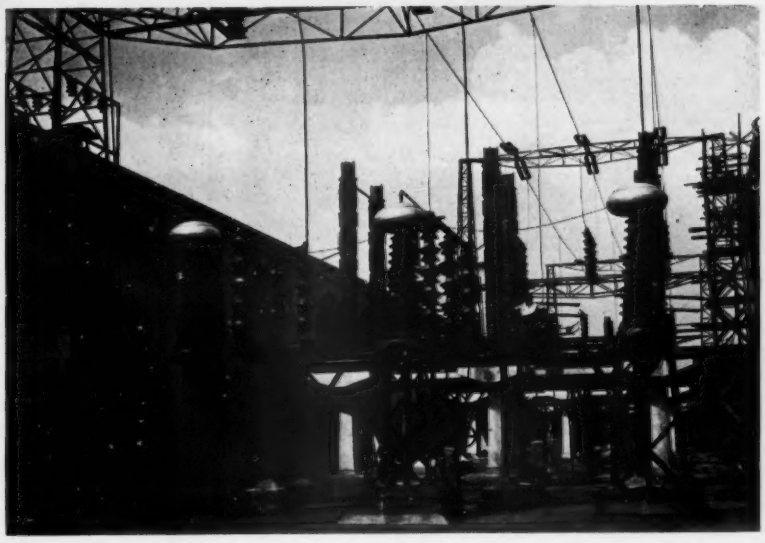

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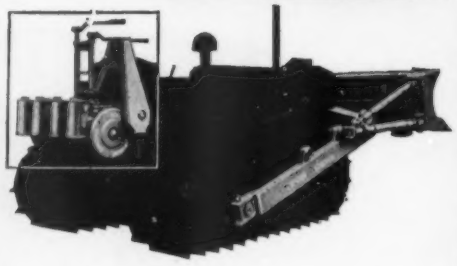

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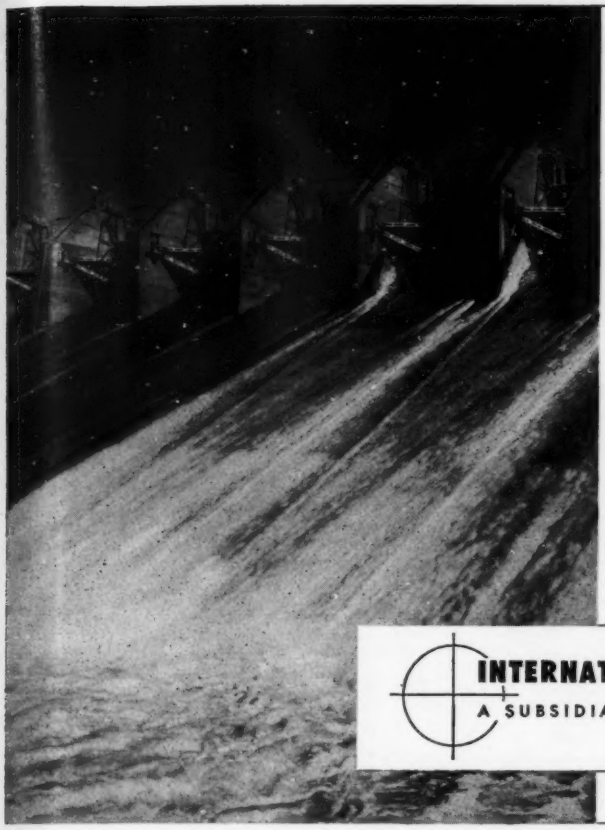

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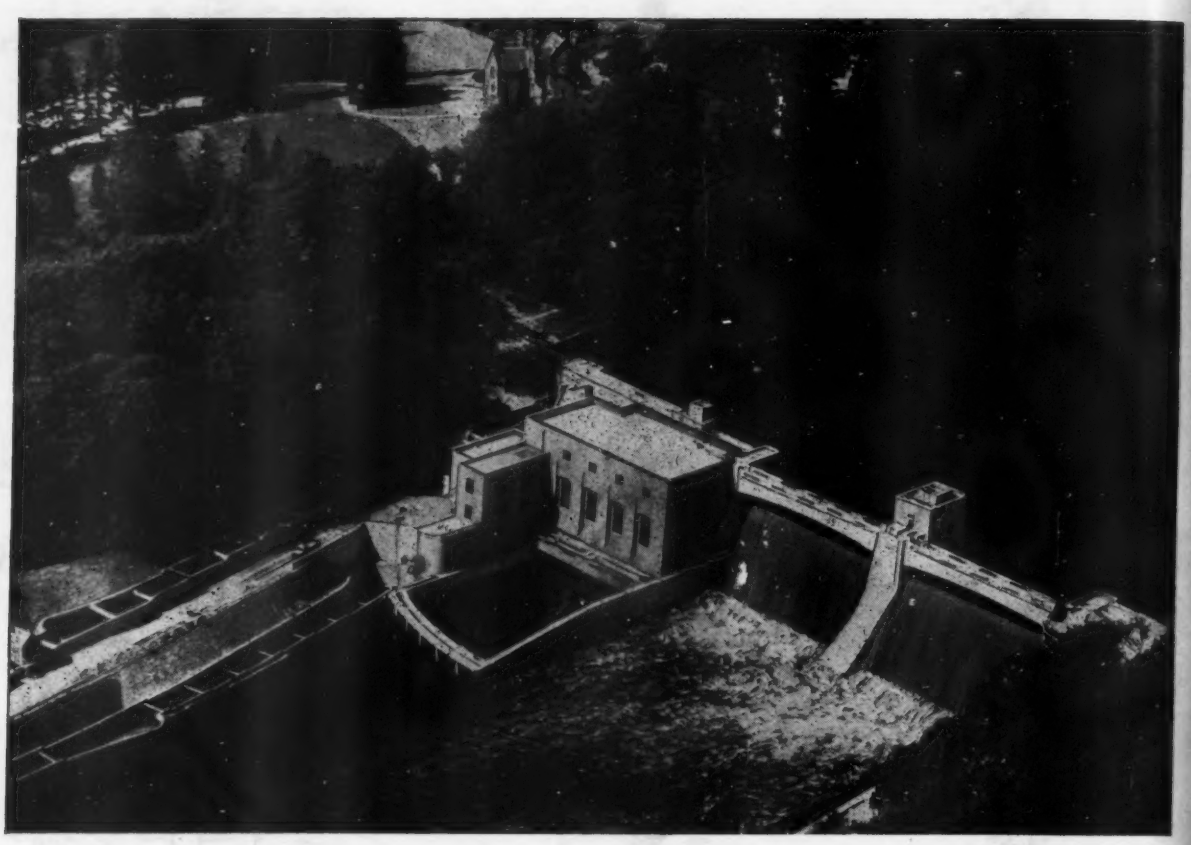

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